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ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning in cooperation with the Committee of Ontario Deans of Engineering has conducted a planning assessment for doctoral work in industrial engineering and systems design. Recommendations for doctoral work in engineering studies are presented. Following these recommendations the consultants report on industrial engineering and systems design is presented. This report discusses the evolution and development of industrial engineering, industrial engineering in Ontario and Canada, and the demand for industrial engineers. Three universities, the University of Toronto, University of Windsor, and the University of Waterloo, are discussed in relation to the nature of programs offered, faculty quality and size, quality of student body, physical facilities, and recommendation. (MJM)

Council of Ontario Universities
Conseil des Universités de l'Ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

11. ENGINEERING 1974*

E. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies

74-22

* The status of this report is given in Item 2 of the statement of principles, on page 1.

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ENGINEERING 1974

E: Industrial Engineering and Systems Design

TABLE OF CONTENTS

This report deals with a planning study of doctoral work in engineering, which was conducted in several portions corresponding to the various disciplines within engineering. The report is in six volumes. Volume A deals with chemical engineering, B with electrical engineering, C with metallurgical and materials engineering, D with mechanical engineering, E with industrial engineering, and F with civil engineering. Each volume contains the COU and ACAP reports for engineering as a whole together with the consultants' report and other material appropriate to one of the disciplines. The COU report will be in three parts: Part I dealing with recommendations approved in June 1974 and dealing with most of the fields, Part II approved in September 1974 and dealing with mechanical and industrial engineering, and Part III to appear later dealing with civil engineering. This volume printed in the fall of 1974 contains Parts I and II.

F O R E W O R D

As a consequence of a study of engineering education in Ontario (described in more detail in the subsequent ACAP report) the Council of Ontario Universities called for a planning assessment of PhD programmes in engineering to be carried out by ACAP in cooperation with CODE.

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

The disciplinary planning process involves a discipline group composed of one representative from each university with an interest in graduate work in the planning area. In the case of engineering, CODE was also involved in a way described in the ACAP report. The discipline group assists in defining the precise academic boundaries of each study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the disicpline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasis of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part I

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering, has conducted a planning assessment for doctoral work in engineering. This arose from the need to re-examine the recommendations concerning PhD work which appeared in Ring of Iron. The background to the study, the procedures followed and the planning techniques used are described in the ACAP report and are not repeated here. The resultant report from ACAP is attached together with the consultants' reports, the comments by the discipline groups, the comments of the individual universities, and the comments of CODE. It is important for the reader to read the attachments in order to understand the recommendations in this Report from COU. COU will issue subsequent parts to this report dealing with mechanical, industrial and civil engineering.

The Council received the ACAP report and supporting documentation on April 11, 1974. The content of the ACAP document was debated on April 11, on May 3, and on June 7, 1974. As a result of these discussions this Report and Recommendations was prepared and approved by the Council on June 7, 1974. The report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments makes this difficult. However, by the summer of 1974 there will have been assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas. On the information and recommendations then available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly-based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plan.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning engineering doctoral work

1. Ontario is unlikely to over-produce engineering PhD's in the next five years. However, the student body contains too large a proportion of non-Canadians. Qualified Canadians should be encouraged to seek the engineering PhD.

2. Doctoral students should be selected on the basis of high academic standing and research potential.

3. "Inbreeding" is a problem, with many students obtaining three degrees from one university.

4. Faculty members, whether or not engaged with doctoral students, should have the facilities and opportunities to engage in research and in work with industry.

5. The scope for inter-university and university-industry cooperation is considerable and should be exploited.

6. The quality and state of development of the Ontario doctoral programmes are variable. Some are very good and have gained international recognition.

7. Some universities are organizing (or reorganizing) doctoral study on a division of specialization other than that provided by the "traditional" engineering departments. In two of the smaller faculties this is a central factor in the planning, but increasing cross-departmental activity is also in evidence elsewhere.

Actions by COU

1. COU has abandoned a planning number of 450 doctoral students and advises the universities to plan on the assumption that the doctoral enrolment will remain roughly constant for the next five years. Although there is a need for engineers with doctorates in Ontario, graduate student enrolment will level off due to a lack of top quality students. Canadians must be attracted in increasing numbers in order to maintain enrolment at the present level.

2. COU requests that CODE report annually to COU on enrolment and employment opportunities.

3. COU requests that ACAP arrange for each engineering discipline group:
(1) to monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students (to ACAP for transmission to COU);

(2) to report annually to ACAP on the universities previously attended by the newly admitted graduate students of each department.

4. COU requests CODE, after consultation with the discipline groups, to develop proposals for collective methods of making information on graduate work in all Ontario universities readily available to the engineering students, and to inform ACAP of the action taken.

5. COU requests OCGS to examine existing university guidelines on part-time doctoral work and its supervision.

6. COU request that ACAP arrange for an annual report to OCGS from each university on the time taken for each graduating student to complete his doctoral studies.

7. COU requests ACAP to examine the available documentation on civil engineering, to reach its own judgements on the basis for a report, after soliciting assistance from the discipline group and the universities, and to prepare its report to COU containing recommendations for the future of civil engineering doctoral work. This should be submitted by December 31, 1974.

8. COU requests that ACAP arrange for the metallurgical and materials engineering discipline group to present a report to ACAP on university actions taken to correct identified weakness in certain fields of study.

Recommendations

It is recommended that:

1. Universities, CODE and discipline groups take steps to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

2. The universities attempt to maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

3. The universities, the provincial government, and granting agencies examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined.

4. All doctoral thesis examining committees have an examiner external to the university.

5. At present, there not be any specific engineering doctoral part-time programmes but rather that part-time or non-resident doctoral work be done by individual arrangement. Experimentation in methods of carrying on part-time work is to be encouraged and might lead in future to the creation of specific part-time programmes. It is also recommended that the research topic of any student accepted on a part-time basis be in a field in which the professors in the department have expertise.

University Recommendations

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

It is recommended that:

6. The University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. If a favourable appraisal is not obtained by the end of October, 1976, admission of new students should then be suspended.

7. The University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained.

8. The involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the university begin doctoral work in agricultural engineering at a time in accordance with the university's plans, subject to normal appraisal procedures.

Chemical Engineering

This section deals with doctoral work in chemical engineering at McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

9. The departments consider grouping their research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

10. McMaster University continue its doctoral work in chemical engineering according to its plans.

11. The University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

12. Queen's University re-evaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the university considers appropriate. If a favourable appraisal has not been received by October, 1976, enrolment of new students then be suspended.

13. The University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to the desirable mobility of its bachelor's graduates for graduate work elsewhere and to the desirability of grouping of research areas. The University of Toronto is requested to report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

14. The University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

The consultants' report is unfortunately inadequate for planning purposes.

It is recommended that:

15. The embargo on the funding of any new programmes in civil engineering continue until COU has accepted a report from ACAP dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted by ACAP by December 31, 1974.

Electrical Engineering

This section deals with doctoral work in electrical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

16. The discipline group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and

make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

17. Carleton University continue its doctoral work in electrical engineering according to its plans.

18. McMaster University continue its doctoral work in electrical engineering according to its plans.

19. The University of Ottawa plan the reorganization of its doctoral programme in electrical engineering and put forward the programme for appraisal. If a favourable appraisal has not been obtained by the end of the fall term 1976, admission of new students should cease. In the meantime, enrolment of new students should be restricted to the digital communications systems and large-scale systems fields.

20. Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields should be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

21. The University of Toronto continue its doctoral work in electrical engineering according to its plans.

22. The University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Metallurgical and Materials Engineering

This section deals with doctoral work in metallurgical and materials engineering at McMaster, Queen's, Toronto and Waterloo.

It is recommended that:

23. The universities take steps to increase the activity in the ceramics, glasses, and polymer fields of study in the province.

24. McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and make a report to COU through ACAP in the fall of 1975 on the following suggestions for improvement:

    a) recruitment of students with physics and chemistry backgrounds
    b) strengthening of the extractive metallurgy faculty
    c) collaboration with the University of Toronto

25. Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors from other departments. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish

to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

26. The University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto consider broadening the programmes and it is requested that the university report to COU through ACAP by September, 1975, on any progress made in this direction.

27. The University of Waterloo continue its doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

It is recommended that:

28. Queen's University continue its doctoral work in accordance with its plans.

General

It is recommended that:

29. In view of the acceptance of these recommendations by the Council of Ontario Universities and the completion of Part I of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on doctoral work in Engineering (except for Mechanical, Industrial and Civil Engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo), in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study has been conducted.

Notes concerning the recommendations

Re: Recommendations 1, 2, and 3

The background to these important recommendations appears on pages 13 and 14 of the ACAP Report.

Re: Recommendation 7

Presumably the programmes submitted for appraisal will be the three divisional programmes which are replacing the departmental programmes.

Re: Recommendation 16

Other engineering discipline groups may also find this a valuable suggestion.

Re: Recommendation 19

This differs from the recommendation in the ACAP Report because the University subsequently decided to carry out a re-assessment of the future direction of the department.

Re: Recommendation 25

Queen's has reported to COU its intention to enlarge its programme in extractive metallurgy.

June 7, 1974.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part II

As Part I of this report indicated it would, this part deals with mechanical engineering and industrial engineering and systems design. Civil engineering will be dealt with in Part III.

The ACAP reports on mechanical and industrial engineering were debated by COU on June 7, 1974. As a result of these discussions, Part II of the Report and Recommendations was prepared and approved by Council on September 6, 1974.

The principles, general observations, actions by COU and recommendations 1 - 5 given in Part I apply generally and therefore have application to mechanical and industrial engineering. Similarly Recommendations 6,7 and 8 deal with doctoral work in engineering at Western Ontario, Windsor and Guelph, and, although the consultants' reports in mechanical and industrial engineering will be of value to these universities, no recommendations for them follow.

Mechanical Engineering

This section deals with doctoral work in mechanical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

29. Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

30. If the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to the need for the department to have suitable industrial and research experience before applying for appraisal.

31. The University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. The University should consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

32. The University of Waterloo continue its doctoral programme in mechanical engineering. The University should consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Industrial Engineering and Systems Design

This section deals with industrial engineering at Toronto and systems design at Waterloo.

It is recommended that:

33. The University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

34. The University of Waterloo continue its doctoral programme in systems design.

Notes: Re Recommendation 33

The University of Toronto is advised to expect about the same enrolment in doctoral work in industrial engineering as it now has, at least until such time as some new field of specialization may be approved.

Re Recommendation 34

The University of Waterloo is advised to give careful attention to the consultants' recommendations for strengthening its systems design doctoral programme before allowing the enrolment to grow.

August 27, 1974.

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES ON ENGINEERING DOCTORAL PLANNING ASSESSMENTS

JUNE 7, 1974

TABLE OF CONTENTS

For each planning assessment (Chemical, Civil, Electrical, Mechanical, Metallurgical, and Industrial) there are appended:

I. RECOMMENDATIONS

General Recommendations

C1

It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

C6

It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

C7

It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

University Recommendations

C10

It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained by that date.

C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

Chemical Engineering

C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

C17

It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

C18

It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

C19

It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted

a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

Electrical Engineering

C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

C24

It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

C25

It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

C26

It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Mechanical Engineering

C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Metallurgical and Materials Engineering

C31

It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these recommendations.

C32

It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:

a. recruitment of students with physics and chemistry backgrounds

b. strengthening of the extractive metallurgy faculty

c. collaboration with Toronto.

C33

It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

C34

It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975, on any progress made in this direction.

C35

It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

C36

It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

Industrial Engineering and Systems Design

C37

It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

C38

It is recommended that the University of Waterloo continue its doctoral programme in systems design.

II. BACKGROUND AND PROCEDURE

In June, 1968, the Committee of Presidents of the Universities of Ontario, after a meeting with the chairman of the Committee on University Affairs, decided that a comprehensive review of engineering education in Ontario should be undertaken. The Committee of Ontario Deans of Engineering (CODE) was requested to draw up plans for such a study, and this proposal was approved by the Committee of Presidents on November 15, 1968. The objective was to create a master plan which could be used as a guide for rational growth of engineering education during the 1970's. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, opportunity for innovation, and maximum freedom of choice for students.

This study culminated in the report Ring of Iron prepared by a commission chaired by Philip Lapp.

The report was received by the Committee of Presidents in January, 1971. A process of review of the report's recommendations was established, CODE prepared a brief based on statements of views submitted by each university concerned and by each Faculty of Engineering. Briefs were prepared also by the Ontario Council on Graduate Studies (OCGS) and the Association of Professional Engineers of Ontario. On October 5, 1971, the Council of Ontario Universities (COU) considered Ring of Iron and the briefs and prepared a statement of recommendations to the universities and to CUA.

COU accepted a number of the Lapp recommendations without change, others with amendments and rejected some. Broadly speaking, the recommendations to do with undergraduate matters were accepted or modified slightly. The graduate area of the report was more controversial, but here also some recommendations were accepted. The most significant of the recommendations concerning graduate study, as approved by COU, are:

> "The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level."

> "Both universities and industries should recognize joint appointments as part of the career structure of their senior staff; these appointments should be increased as far as possible..... By this we understand a system of part-time appointments."

> "Over the next two years the estimated graduate enrolment of 2,000 full-time equivalent students for 1970-71 be reduced by 17%, after which graduate enrolment should be limited to a number equal to the previous year's bachelor graduations. The enrolment figure applies to the engineering departments as identifed in Ring of Iron".

"The recommendation that the number of PhD students enrolled be reduced to 450 per year is fully supported by all groups including COU. However, COU, along with CODE and OCGS, recommends that the figure of 450 be the target for 1974-75, rather than for 1973-74, for reasons related to avoiding large fluctuations in enrolment as explained in the OCGS critique."

"The Lapp report recommends specific numbers of PhD enrollees for each of the universities including discontinuance of the PhD enrolment in certain universities. COU feels that the reasons for the numbers chosen or for the elimination of certain doctorate programmes are not fully documented in the Lapp report. COU also agrees with CODE and OCGS that attention must be given to the numbers of doctorate enrollees by discipline as well as by university. For these reasons COU recommends that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programs to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

On receipt of this instruction from COU, ACAP and CODE established a liasion committee (Ayers, Dillon, Ham, Johnson, Shemilt, McIntosh, Preston) which drafted procedures for the assessments. It may be noted that the committee considered a model in which the assessments were based, not on the five traditional departments found in engineering faculties, but rather on interdepartmental areas of research; the practical difficulties of conducting the assessments led the committee to recommend the five-fold subdivision actually used.

The procedure developed in this way was approved by ACAP on March 17, 1972, and by COU on April 7. The procedure (except for minor data amendments) is that in Appendix D to this report. In writing to indicate its

approval CODE expressed their understanding that two objectives would be met:

"1. To provide a rational basis for doctoral work in engineering and for confirming or modifying the limitation on enrolment suggested by Lapp.

2. To conduct a really effective assessment of the quality of our current doctoral programmes."

CODE went on to emphasize the need of adequate resources to obtain the best consultants.

In order to begin the planning assessments, the ACAP/CODE liasion committee called a meeting of members of the five Discipline Groups (Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering). This meeting on April 12, 1972, indicated a good deal of faculty resistance to the conduct of the planning assessments and uneasiness about some perceptions of some aspects of the approved procedures. This resulted in a delay in mounting the assessment. CODE suggested a Coordinating Task Force, consisting of two members of CODE, the chairman of each Discipline Group, and a member of ACAP could review the procedures. ACAP advised COU to agree to this request and the COU executive did so on June 9, 1972. This Task Force held meetings on June 29, July 27, September 1, September 25, November 29, 1972 and March 19, 1973. It suggested two slight additions to the procedures as approved earlier by COU. These were approved by COU on September 25, 1972. The Task Force also produced a document clarifying some aspects of the procedure in detail, and a statement of some educational philosophies concerning doctoral study. These documents are referred to in the terms of reference of the consultants. The Task Force also advised ACAP (and so did universities) on how to take into account for planning purposes those doctoral programmes in Faculties of Engineering which did not fall obviously into the fields covered by one of the five consulting teams. It was eventually decided that:

a) both the metallurgy and the mechanical engineering consultants would be asked to consider the metallurgical work within the Department of Mechanical Engineering at Waterloo

b) no advice from external consultants would be sought on the doctoral programme in mining engineering at Queen's

c) a small-scale "planning assessment" involving two consultants would be carried out in industrial engineering and systems design

d) in view of the fact that all current doctoral students at Guelph are in hydrology and that the field of agricultural engineering is also proposed, the civil engineering consultants would be asked to consider the Guelph doctoral work, with the understanding that if they so wished ACAP would facilitate a consultation for them with someone in a department of agricultural engineering

e) the mechanical engineering consultants be asked to consider the doctoral work at the University of Toronto Institute of Aerospace Studies and in aeronautical engineering at Carleton, with the request that they consult also with another of the ACAP consultants (on the Electrical Engineering team) who had expertise in some of the UTIAS work outside mechanical engineering and also with an aerospace specialist

f) advice on the future plans of the Department of Management Science at Waterloo would be sought from the consultants in the planning assessment in Administration, Business and Management Science, with a comment also provided by the consultants on industrial engineering.

g) no special arrangements were needed in connection with biomedical engineering at Toronto since the corresponding institute has no graduate programme of its own, and the future doctoral plans are covered in the statements from each of the associated departments.

Item f will be dealt with in a later report. The remainder are covered in this report. The mechanical engineering consultants informed ACAP that they did not require the assistance suggested in item e.

In October, 1972, CODE proposed that a study be carried out, under the aegis of the newly established Canadian Engineering Manpower Council, and with financial support from a number of agencies, in order to make recommendations about "supply and demand" for engineering doctorates. This would be expected to be of great value to the planning assessments. ACAP agreed to this suggestion, provided funds towards the costs, and incorporated reference to the study into the instructions for the consultants. In the event, the study proved rather disappointing; it is discussed later in this report.

As a result of suggestions from the Discipline Groups and after receiving comments from the Coordinating Task Force and from CODE, ACAP agreed on consultants at its meetings of September 7-8, October 13 and December 18, 1972. The consultants who finally acted were:

Chemical Engineering:	Dean P. Grenier of Université Laval, Dean W. R. Marshall of the University of Wisconsin, Professor L. Yaffe of McGill University
Civil Engineering:	Professor W.W. Eckenfelder of Vanderbilt University Mr. E. V. Martin of Alan M. Voorhees and Associates Ltd., Professor G. G. Meyerhof of Nova Scotia Technical College, Dr. J. L. Boulet of Hydro-Quebec.
Electrical Engineering:	Professor A. D. Moore of the University of British Columbia, Professor M. E. Van Valkenberg of Princeton University, Dr. M. P. Bachynski of RCA Research Laboratories

Mechanical Engineering:	Professor H.W. Emmons of Harvard University, Dean G. Ford of the University of Alberta, Dr. R. D. Hiscocks of the National Research Council of Canada, Professor S.G. Mason of McGill University
Metallurgical Engineering:	Professor J.J. Jonas of McGill University, Professor T.B. King of the Massachusetts Institute of Technology, Professor W.S. Owen of Northwestern University and M.I.T., Dr. W.B. Lewis of Atomic Energy of Canada Ltd.

Brief curricula vitarum appear in Appendix G. In each case, the last named person played the role of a senior Canadian from outside the discipline.

The consultants held their first meetings at various dates in April and May, 1973 and in each case met with the appropriate Discipline Group, arranged the schedule of visits, discussed their character and had general discussion with the Discipline Group about the task before them. The visits took place in the two or three months following these meetings.

The consultant teams each submitted a draft report in September, which was the subject of oral discussion with the Discipline Group at a meeting within a few days of the receipt of the draft. Each consultant team then submitted its report. These reports were sent for comments to the universities, to the Discipline Groups and to CODE, each of which sent comments to ACAP at various dates in November, December and January.

A subcommittee of ACAP began consideration of the report to COU, before all the comments were in hand and continued its work through March, 1974, reporting regularly to ACAP and receiving instructions. Early in its meetings the committee identified some points on which further information and reactions were required. In particular, the need for fuller advice from the consultants. was felt in the cases of civil and mechanical engineering. Such further advice was sought, with results discussed in the relevant sections of this report. ACAP also thought some further information would be helpful in connection with three of the universities and arranged meetings with officials of these universities and members of ACAP.

This report is based on the consultants' reports, the data collected for the study, the universities' comments and supplementary material from some of them, the Discipline Groups' responses, and the other documentation referred to in the procedures and terms of reference. The report sets out recommendations for COU on doctoral work in engineering in Ontario for the next few years.

As is required, ACAP presents this report directly to COU. It has also been transmitted for information to OCGS, CODE, and the Discipline Groups.

III. GENERAL RECOMMENDATIONS

This section of the ACAP report contains recommendations that are of general concern to all of engineering. Some of these recommendations have been mentioned consistently in all the reports while others, although found in only one report, are applicable to all doctoral programmes.

Enrolment and Manpower Forecasts

In the summer of 1973, the Canadian Engineering Manpower Council released its report entitled Supply and Demand for Engineering Doctorates in Canada. This report was partly financed by ACAP and was given to all the consultant teams prior to their writing of their reports. It generally states that the supply of engineers in the next five years will exceed the demand.

A summary of the comments made by the engineering consultants concerning this report shows that they all independently disagree with the projections made in the CEMC report. They believe there has been no overproduction of PhDs to date and, in fact, there appears to be a shortage of metallurgical PhDs. Each team believes that the need for engineers will not decline, as predicted by CEMC but that the overall demand will continue and in actual fact, all but the civil engineering consultants believe it will increase.

ACAP had originally intended to publish a critique of the CEMC report. However, CODE in its repsonse to the engineering reports, Appendix H, has included a statement on this report covering all the points ACAP wished to make. ACAP's critique will not be reproduced, but we feel that the CEMC report is not an adequate basis for manpower planning in engineering. Since all the consultants agree that supply will not exceed demand but perhaps rather the reverse, the question of supply of qualified students must be studied. The main problem will be attracting Canadians into engineering graduate work. In 1972-73, of the 518 F.T. engineering PhDs, 28.6% were Canadian, 53.3% were landed immigrants and the remaining 18.1% were on student visas.

Changes in the immigration regulations make it harder to become a landed immigrant. Since one can no longer apply for landed immigrant status while in Canada, those that come on student visas will presumably return to their homelands. Coupled with this is another new regulation that a teaching assistantship is no longer classified as a job, thus making it harder to obtain landed immigrant status. Consequently, ACAP feels that the percentage of landed immigrants in graduate work will drop while the number of students visas will increase. Financial support for people on student visas is scarce. There are very few scholarships or bursaries open to them but in engineering they may be

supported from contract funds. In any case, there will be funds for only a few. Although Canada has a role to play in providing advanced technical education for the underpriviledged countries of the world, this should be kept to a reasonable level and should not exceed 30% of engineering doctoral enrolments.

CODE, on page H-9 of its response, states that "unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline". There are suggestions that student stipends be increased. We remain unconvinced that stipends need be any higher in engineering than in any other field, but there is one exception and this is that people with substantial professional experience returning to graduate study should be supported at a higher level.

ACAP is inclined to agree with the University of Waterloo's comment, page G-29 in its response to the chemical engineering report, that the best way of attracting Canadian students is a "change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry". Increased dialogue with industry as well as up-to-date information on jobs available would make the employment picture brighter and more alluring to prospective Canadian graduate students especially if the number of industrial scholarships were increased and more interaction were seen to be taking place between industry and university.

This dialogue with industry is needed to ensure that more Canadians continue in graduate work. If industry indeed has a place for the master's or doctorate in engineering, more must be done to encourage good students to stay in university instead of taking a job after the bachelor's degree. Industry in its hiring policies can encourage this.

The chemical engineering consultants recommend that the universities should endeavour to develop entrepreneurship in students. They feel "this is a quality so badly needed at present in Canada".

It does not seem as though Ontario will overproduce engineering PhDs in the next five years. The question is rather whether there will be enough qualified students. In view of this possible shortage, the following recommendations are made by ACAP.

Recommendation C1

> It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

Recommendation C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

Recommendation C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

Recommendation C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

Admissions

ACAP does not support the view held by the electrical engineering consultants, namely that admitted doctoral candidates should have first class standing and proven research ability. Many students who graduate with high second class honours have become excellent research engineers. The usual minimum standard of the better departments is a high B and all the consultants agree that high standards of admissions prevail generally.

Recommendation C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

CODE agrees with ACAP on the annual post facto analysis of admission practices (page H-3). The chemical engineering consultants have suggested "that should it be found that students have been accepted who, in the opinion of the committee, do not fulfill the minimum requirements, the committee advise COU that a recommendation be made to the requisite authority suggesting no BIU be awarded for that student". ACAP does not feel this to be necessary at the present since regular reporting by the Discipline Group should exert considerable pressure if an institution

repeatedly admits students of a low standard.

Undergraduate-Graduate Relationship

Some consultants assert that each department should provide all levels of study: bachelor's, master's and doctoral. Some go so far as to say that a doctoral programme in each department is essential. CODE, on the other hand, feels that what is important for a good undergraduate programme is research and professional activity by the faculty, and that this can be carried forward without graduate students, although at present the research activity is most easily carried on through graduate programmes (page H-3). ACAP agrees with the position stated by CODE and indeed applies it to all subjects, not only engineering, but with the comment that in many fields it is not difficult for a professor to be active in research without having graduate students. We would point out that the other position would imply that no department should exist unless it can operate an effective doctoral programme, a view which we find impossible to accept. The absence of sufficient research and professional activity by professors would raise questions about the quality of a department and hence of its undergraduate offerings, whether or not it offered doctoral work.

Thesis Quality

Recommendation C6

> It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

Since some of the consultants have made reference to the make-up of examining committees ACAP would wish to endorse this practice of including an external examiner.

Critical Size

We agree with CODE that there must be sufficient range of interaction for the student and that the judgement as to the presence of this interaction must include consideration of the involvement of persons outside the student's department and should include post-doctoral fellows and research associates as well as students. Although these planning assessments were vertical, as CODE suggests, each department was asked to state the extent of this interaction in its university. We agree that there is no *a priori* reason why a small school cannot provide as satisfactory an environment as can a large school. The question is not one of principle, but one of fact: does university A in fact provide the requisite environment for interaction for the average student in its department X?

Most of the consultants considered this question carefully and made specific comments but others provide no evidence that they examined the matter in

any of the universities. While most agree that successful programmes can exist in small as well as large departments, the consultants still expect a wide range of courses to be offered. This in turn requires a certain number of students to make the courses economically feasible and academically stimulating.

Mobility of Students

The chemical engineering consultants are concerned about the lack of mobility of engineering students. They do not consider it a good educational experience to study for all three degrees, the bachelor's, the master's and the doctorate, at the same university. Such a programme leads to inbreeding and sameness and precludes any chance for the student to come in contact with different faculty, students, milieu and methods.

One sometimes hears a professor accept this in theory, but then say that in practice the student must not be prevented from going to the university of his choice. That view appears to us to be correct, provided the student's choice is made on sound academic grounds, based on good information of the opportunities that are available to him, and taking account, of course, of the undesirable aspects of remaining in one university.

Recommendation C7

> It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

Part-time Programmes

In 1972-73, 18% of the doctoral students studying engineering were doing so on a part-time basis. 65% of these students were Canadians and another 32.5% were landed immigrants. It would appear that these part-time programmes are being used by the profession to upgrade the skills and knowledge of its practising engineers.

The consultants seem divided on the issue of part-time programmes, some saying "such undertakings should be rarely encouraged" and others, "full encouragement should be given to part-time doctoral programmes." ACAP feels that there is a place for the part-time programme and that careful attention should be devoted to designing part-time programmes, bearing in mind the strengths of the departments. One of the dangers sometimes noted is that students become involved, under a part-time supervisor, in a project in an area in which the full-time staff has limited expertise; this is not recommended.

Recommendation C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

Cooperation

One of the main points that all the consultants agree upon is the need for increased cooperation both within and between universities. The chemical engineering consultants found a need for increased interaction between the engineers and the pure science faculties. Some of the other consultants felt the need for more communication and cooperation between the universities and industry and government. Lastly, more effective use could be made of the resources in the province if the universities themselves joined together in some form of cooperative endeavour. CODE endorses this last point quite strongly in its response, page H-4. Sharing of equipment, discipline meetings and an interchange of credits for graduate courses are a few of the methods listed by CODE that are to be encouraged on the way to making this cooperation a meaningful and workable venture. ACAP concurs with the statements made by the consultants and CODE and strongly supports their implementation.

ACAP intends to request that each Discipline Group report regularly to ACAP on interuniversity cooperative arrangements.

Faculty

Two sets of consultants found enough disquieting evidence in the engineering faculties of the province to suggest that the requirements for a faculty member, eligible to supervise graduate students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty with proven research ability and productivity supervise graduate students.

Since this concern has been mentioned in other assessments, ACAP feels it is time that OCGS conduct a review of this area.

Time to Reach Degree

The electrical engineering consultants were concerned about the length of time taken to obtain the PhD. As they pointed out, the average student at one university took 13-20 months longer to complete his doctorate than his counterpart at another university. As a whole, they found the average time of study to be excessive.

Recommendation C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

IV. UNIVERSITY RECOMMENDATIONS

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

University of Western Ontario

The University of Western Ontario began to offer doctoral work in engineering in 1965. Since then, twenty PhDs in Engineering Science have been granted. From the beginning effort has been made to emphasise its interdisciplinary nature and there has been a limited number of areas in which the student may do his graduate training. At no point has a doctoral degree been given in the so called traditional fields of engineering.

There are seven main research areas in which a student may obtain a PhD in Engineering Science. They are 1. Geotechnical 2. Boundary Layer Wind Tunnel 3. Chemical and Biochemical Process Development and Design 4. Material Science 5. Systems 6. Applied Thermodynamics and 7. Applied Electrostatics. Environmental engineering aspects can be studied in all these research areas except Material Science.

Western's response to the collective engineering picture gives the 1973-74 enrolment as 29 F.T. and 15 P.T. doctoral students. In the additional data given to ACAP, 18 of the 37 current students' programme of study outlined were in the chemical engineering field, 8 were civil, 5 mechanical, and 3 each in electrical and material science.

The chemical engineering consultants have provided evidence of that programme's being of good quality. The systems research area depends heavily on chemical engineering. ACAP, therefore, concludes that the research areas Chemical and Biochemical Process Development and Design, and Systems are of satisfactory quality.

The metallurgical engineering consultants have recommended that the Material Science programme become a part of an interdisciplinary programme rather than an exclusively material science one. This was in part based on the fact that the group is small and spends most of its time teaching at the undergraduate level. They are "carrying a large programme for a group which is subcritical in size." From the additional material supplied by Western, there is little evidence of interdisciplinary activity for students who might be doing research in this area. ACAP concludes that this area should not be operating at the doctoral level.

The areas of mechanical engineering doctoral research work are subsumed under the main research area, Applied Thermodynamics. The consultants indicate that the doctoral research connected with heavy water is of good quality but they raise very serious questions about the doctoral work in acoustics. They feel this area should be restricted to work at the master's level.

The civil engineering consultants did not make comparative judgements, but from some of the phrases used to describe the Boundary Layer Wind Tunnel Laboratory such as "internationally known", ACAP has no reservations in recommending continuance of doctoral work in this research area, even though it appears to have little interaction with other groups. The civil engineering consultants told us nothing about the Geotechnical area and we, therefore, had difficulty in recommending a position to be taken with regard to this field.

The last research area, Applied Electrostatics, is the most difficult to assess. The electrical engineering consultants have recommended discontinuance of the doctoral programme. They feel the students are getting too narrow a training in electrical engineering. We observe, however, that the students are not considered to be studying for a PhD in electrical engineering, but rather for a general degree in engineering science. Although there are only a few faculty members in this area, they are internationally known. The main problem would, therefore, seem to be the extent to which the doctoral training in this area is of an interdisciplinary nature. From the data available to ACAP, we are unsure.

In the course of discussions with representatives of the University of Western Ontario, it became clear that the Faculty is involved in a thorough re-examination of its doctoral programme. It is committed to the concept of an engineering science PhD but is reconsidering the appropriate areas of research. While it is not entirely accepted by ACAP that all the activity is noticeably different from that in engineering departments elsewhere, we nevertheless believe that this intention of the Faculty should be encouraged. A corollary is that it must be very careful about the research areas in which it accepts PhD candidates; we have already commented on these and note the standard of quality seems variable.

These considerations have led us to formulate the following recommendation.

Recommendation C10

> It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

University of Windsor

Early in 1971, the Faculty of Applied Science at the University of Windsor began to examine the structure of graduate programmes within the Faculty in order to improve their operation, avoid needless and costly duplication of graduate course offerings and to attempt to create a greater cross-fertilization of research by involving faculty members from different engineering departments in various facets of a larger research plan. This examination led to the recommendation that Graduate Studies be operated on a divisional basis, with the seven undergraduate departments being consolidated under three graduate divisions, namely Engineering Process Design, Structures and Systems. The three divisions would each elect a chairman who would decide on course offerings and enrolment levels. The three chairmen, one elected member from each division, one graduate student and the Dean of Applied Science form a Coordinating Committee to oversee and coordinate the wishes of the Divisions. This plan was approved in Spring 1972 and is now being implemented.

Some of the traditional departments such as chemical and electrical fall completely in one division. All the rest are split between two as can be seen in the attached Table 1.

There are nine identifiable research areas, each of which have participating faculty from at least two of the old departments and these nine areas are in turn divided fairly equally among the three divisions.

The degrees awarded will retain the old titles, for example, a PhD in Chemical Engineering, but the interaction of the individual student with others in the Faculty will be greatly enhanced. Depending on his research topic, the student might take as many as half his courses from professors in other 'departments'.

The consultants' comments concerning Windsor vary, but a number of their reports imply some doubt or uncertainty concerning the relevant departmental programme, either with respect to the situation at the time of their visit, or in connection with its future direction. The chemical engineering consultants suggest that Windsor be reviewed in greater depth. The metallurgical engineering consultants recommend the integration of engineering materials faculty in the new divisional system. The mechanical engineering consultants call for more emphasis on master's work. In the case of electrical engineering the consultants indicate that good work is now being done in doctoral education in two fields, agree with the present plans for no significant growth in enrolment and for no expansion of fields, and go on to recommend a review after five years.

In view of these considerations ACAP feels the University of Windsor should be given time to produce a viable interdisciplinary system of doctoral engineering studies before that system is brought forward for appraisal. This appraisal would determine the level of quality in the new divisional system and whether or not significant interaction has been achieved between the staff and students of the various departments.

Table I

Organization of Engineering Doctoral Work at the University of Windsor

a. % of Department Involvement in each Division

Department	Engineering Process Design	Structures	Systems
Chemical	100%		
Civil	40%	60%	
Electrical			100%
Engineering Materials	50%	50%	
Industrial	10%		90%
Mechanical	60%	40%	

b. Departmental Research Interests

Department \ Research Interests	Structures	Electric Power	Thermofluids	Systems and Signals	Human Factors	Mechanical Metallurgy	Physical Metallurgy	Water and Air Quality	Vibration and Noise
Chemical			x					x	
Civil	x		x			x		x	x
Electrical		x		x					
Engineering Materials	x		x			x	x		
Industrial				x	x	x		x	x
Mechanical	x		x	x	x	x			x

Recommendation C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977 if a favourable appraisal has not been obtained by that date.

University of Guelph

The University of Guelph has for sometime offered an interdepartmental PhD programme in Hydrology in which its Engineering School plays a part. It also plans to develop doctoral work in agricultural engineering, which it already offers at the master's level. There are no other programmes in agricultural engineering in the province.

The matter of the interdepartmental programme would appear not to be central to this assessment. It would not be inappropriate for the Civil Engineering Discipline Group to keep this programme in mind when carrying out the study called for in Recommendation C19. Nevertheless, it seems unnecessary to await the Discipline Group report to make the recommendation which follows.*

From the planning viewpoint, there seems no reason to do other than accept the University's intention to begin doctoral work in agricultural engineering, whenever it feels the time is ripe and the proposal has passed appraisal.

Recommendation C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

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* It may be noted that COU did not accept Recommendation C19.

V. CHEMICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the chemical engineering consultants' report. There will be no reference made to Western or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C13

> It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

Recommendation C14

> It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

McMaster specializes in process simulation, waste-water treatment, polymer engineering, chemical reaction engineering and catalysis, and transport and separation processes, with stronger emphasis on the first two areas. The consultants feel that McMaster's goals for the future are "realistic" and appear to be "achievable and productive".

Recommendation C15

> It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

The University of Ottawa specializes in three main areas including thermodynamics and transport properties; kinetics, catalysis and reactor engineering; and transport processes. There has recently been a shift towards a greater environmental emphasis. The consultants encouraged Ottawa to keep up with changes in the areas of research and graduate teaching and move into these new areas whenever possible.

Recommendation C16

> It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

Queen's University specializes in the following five doctoral research areas: biochemical and environment engineering, chemical kinetics and reactor design, process control and simulation, thermodynamics, and transport phenomena. These areas cover most of chemical engineering making a rather uniform distribution of effort. The publication records of only two professors are very good, all the rest being average or low. This raises questions as to the activities of the faculty since their connections with professional and scientific societies can be described as "only mildly active". The consultants feel alarm at the number of Queen's bachelor's graduates who undertake graduate work at the same institution.

On the optimistic side, the consultants note that "the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province".

ACAP suggests that Queen's might consider strengthening its present faculty, or alternatively, it might consider consolidating its existing wide scope of research areas. As to inbreeding of students, ACAP draws Queen's attention to Recommendation C7.

Recommendation C17

> It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975 on action taken in regard to this Recommendation.

The University of Toronto lists eight areas of specialization, all of which show a rather uniform distribution of faculty effort. The exception is a marked emphasis on applied chemistry. The consultants would like to see an effort to group the staff in given areas of research instead of the present policy of allowing a staff member "to select his own path". The consultants did not find Toronto's statement on its plans particularly helpful and they offered no comment on it, other than to say that "it is doubtful whether any increase above the present enrolment would be beneficial to these new students or to the student body as a whole". The University of Toronto should also encourage mobility of its graduates to the benefit of other departments and of the students alike.

Recommendation C18

> It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

The University of Waterloo has grouped its research activity into five areas including biochemical and food engineering, extractive and process metallurgy, polymer science and engineering, mathematical analysis and control, and transport processes and kinetics. The scope is wide, covering a large part of chemical engineering but, there are defined groups to coordinate the programmes. Although the consultants considered the statement of goals and objectives "less positive and definitive" than others, they were pleased to note Waterloo's intention "to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary".

VI. CIVIL ENGINEERING

The report of the civil engineering consultants contains a number of important recommendations of a general character.

Their discussion of the manpower situation supports our Recommendation C1. They suggest that it would be wise to expect rather fewer students than the totality of the stated university plans. Considering the uncertainty of the manpower analysis and the size of the numbers involved, ACAP does not feel it desirable to formulate any recommendations about individual enrolment. ACAP does advise each university to consider the likelihood that the doctoral enrolment in civil engineering may fall still further unless the fraction of Canadian students increases substantially from its present level of about 25%.

Their comments that the "study of a civil engineering speciality in depth necessitates increasingly...some graduate work", reinforces our Recommendation C2 concerning publicizing the value of graduate work.

They argue for more part-time work and closer liaison with industrial and governmental laboratories. Recommendations C2 and C8 touch on this point.

The consultants on pages A-18 and A-35 express their concern that students tend to remain for graduate study at their undergraduate universities, often being unaware of offerings elsewhere. We make recommendations on this problem in Recommendation C7.

The consultants perceive a need for "more consistent requirements of acceptance....between universities". Although we do not recommend the particular remedy they suggest we do make Recommendation C4 in this connection.

On matters specific to civil engineering, the consultants stress the need for more emphasis on fields other than structures. They call for less stress on "traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation". They suggest that "change of programme emphasis in civil engineering (will) lead to some growth in faculty when generally universities are expecting a fairly static period". On pages A-49 and A-50, they quantify this shift by asking for a 20% reduction in doctoral enrolment in structures (i.e. a drop of about 15 students) together with a corresponding increase, roughly equally in transportation and water resources. Perhaps rather surprisingly they then suggest that no university should offer a new field at the doctoral level. (On page A-52 they also suggest that no university reduce "the range of its doctoral programmes" but on page A-51 they add "unless that university desires otherwise".)

The consequence of this stance, based on pages A-25 to A-29, is summarized in Table 2.

Table 2

CIVIL ENGINEERING

Possible Consequences of the Consultants' Recommendations on Enrolment and Field Emphasis

Universities	Fields				Order of Magnitude of Enrolment
	Geo-technical	Structures	Water Resources	Transportation	
Carleton	S	R	-	I	6
McMaster	-	S	I	-	10
Ottawa	S	R	I	-	17
Queen's	S	R	-	-	8
Toronto	S	R	I	I	25
Waterloo	S	S	I	I	30

LEGEND: R - reduce enrolment
S - static enrolment
I - increase enrolment

NOTE: Guelph, Western Ontario and Windsor are not included in the chart as they are dealt with elsewhere. (See section on University Recommendations.)

There are difficulties in accepting these recommendations. For example, if one asks what the shifts of enrolment from structures would be, to total around 15, one comes up with something like: Carleton 2, McMaster 0, Ottawa 3, Queen's 2, Toronto 4, Waterloo 4. Looking then at transportation one finds doctoral programmes at Carleton, Toronto, and Waterloo which might increase by 2 or 3 at each place. One has to ask if this is the best way to develop more high quality doctoral work. Would it be a better strategy to encourage Carleton, for example, to build a somewhat larger group than 3 or 4 students? There is another concern. Are all the transportation groups of equal promise as places to do doctoral work? If not, should some be strengthened more than others? If we really believe in penny-packet enrolments, could a fourth university perhaps enter this field? The consultants' report provides no satisfactory discussion of these questions to justify its proposals.

Equally unsatisfactory, and perhaps more basically disturbing, is the consultants' failure to give any discussion whatsoever (with three small exceptions) of the facts and reasoning which led them to conclude that all existing programmes are satisfactory. This may be so, but the rationale is far from clear. As the appended correspondence (Appendix 1 to this section) shows, the consultants decline to discharge their terms of reference, in particular C3c and the paragraph following C3d. (See Appendix D).

In particular, although the matter of critical academic enrolment size is discussed in generally acceptable terms, in that the proposition is stated that there is no a priori reason to assume a small school cannot provide as satisfactory an environment for a PhD student as a big school, the consultants neither state the characteristics of such an environment nor do they make any effort to show that it exists in the several small programmes they examined. Although it is no doubt possible to make the justification in several cases, nevertheless a question must still loom unsettled as to the academic strength (from the potential students' viewpoint) of several of the programmes, namely Carleton, Guelph, McMaster, and perhaps Ottawa and Queen's. (None has been appraised.) Of course the consultants' report, due to the lack of rationale in it, gives no reason to suppose that the larger departments are necessarily of suitable quality either.

ACAP cannot justify to itself recommending the acceptance of the consultants' plan, calling as it does for static enrolment, small shifts of emphasis in fields, and no new developments in any department. We feel that the question of the best way to develop doctoral work in transportation and water resources must be more carefully canvassed and that whatever the answer be it must be adequately justified. Some evaluation of the quality of the programme in each broad field at each university must be available before we can make any credible recommendation.

ACAP would like, at this point, to draw attention to the Discipline Group's response, Appendix B. The members of the group feel the consultants did not "seize their unique opportunity to make quality judgements" and failed to "address themselves to the question of quality in the planning function

in their conclusions and recommendations." The group thinks that a statement that "documents the sundry strengths and weaknesses, if they exist, could well increase the value to those on whom the responsibility for planning ultimately rests". ACAP therefore makes the following recommendation.

Recommendation C19

> It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

We regret that this recommendation is necessary. We note (page A-5) that the Discipline Group had not prepared for the consultants the report called for by the agreed procedure (page D-6). We note also that the consultants state that they "have formed (their) own judgement about the strengths of different civil engineering departments and the areas in which they are likely to be able to attract high quality students" - we regret that the consultants are not willing to share these judgements with the Ontario university community which employed them.

APPENDIX 1

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

21 February 1974

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

Further to our recent telephone conversations, I have now heard from all my colleagues who fully agree with my letter to you of 4 December 1973.

As mentioned in this letter, we did not discuss the question of quality in our Report since none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

Moreover, we did not feel the need, nor were we required by our terms of reference, to make relative quality judgements regarding the strengths or weaknesses of individual areas or departments, because in our Report we did not recommend any change in the number or the range of doctoral programs offered by any school, including the various areas of specialization of the smaller universities.

Since the civil engineering discipline group, as well as most universities, find our Report on the whole acceptable, we think that little is gained by getting into an area which might be interpreted as an appraisal or accreditation assessment.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb
c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

4 December 1973

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

After returning from the west coast, I found your letter of 29 November and enclosures, which I read with interest.

In reply and following our terms of reference, we had not discussed the question of quality in our report since, in our opinion, none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

I am looking forward to the comments of my colleaques, in this regard.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb

c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
102 Bloor Street West Toronto 181, Ontario
(416) 920-6865

Postal Code: M5S 1M8

November 29, 1973

Mr. B. V. Martin
Prof. G. G. Meyerhof
Prof. W. W. Eckenfelder, Jr.
Dr. J. L. Boulet

Gentlemen:

I am enclosing all the university comments we have received on your planning assessment report and the formal response from the Discipline Group. You will recall that it is intended to publish these statements.

You will see from the comments that there is considerable dissatisfaction in the universities and in the discipline group with your failure to come to terms with your task of giving us your findings on the relative quality of the doctoral work in the different areas of civil engineering in the different departments. We on ACAP have to agree that one of the most important aspects of the terms of reference you undertook is the statement of strengths and weaknesses of departments, and that without it the report lacks credibility. If you are asserting that all fields offered for doctoral work are competently dealt with wherever they are offered, it will follow that civil engineering is a paragon amongst disciplines. Even if true, it does not help the universities to decide which areas to strengthen.

In one of the few specific comments, you do suggest that McMaster should emphasize earthquake engineering. Do you think its work in water resources is strong enough that it should seek to expand or maintain that, or, when you recommend greater emphasis on water resources, do you expect this to be achieved at Ottawa, Toronto, Waterloo and Windsor for example? McMaster (and the others) would like to know. You tell the University of Western Ontario to emphasize boundary layer wind tunnel work; but what about their geotechnique? Since Guelph now has 5 students in its hydrology programme, how can it be exploiting its unique facilities for agricultural engineering if its enrolment becomes 4 to 7? Is it expected to cut back on hydrology? To consider this, it would be necessary to know how valuable Guelph's hydrology work is and how substantial is the potential of its agricultural engineering programme.

I mention these points only as examples of the kind of question on which your advice would be helpful. The general point is that your judgements of quality by department and by area are important. You recommend that transportation be strengthened; we ask, where? If all the departments say "here", how are decisions about resource allocation to be made without the quality judgements you were expected to give?

....2/

One of the aspects of academic quality has to do with the size of the student enrolment. You will see from the university responses that there is some difference of opinion. The official position of COU, recently adopted, is as follows:

"The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design."

Recommendation 4 on page 52 of your report is not inconsistent with the above statement, but you do not indicate what criteria determine the "satisfactory environment." In ACAP we have identified two areas which we believe should be examined in this connection. One is the opportunity for the students' development through informal intellectual discussion with a peer group with common engineering or scientific interests. This peer group need not consist only of students; it may also include post-doctoral fellows. It need not be confined to one department, but may include students in other departments if there is a real sharing of research interests. The second main area for consideration has, we feel, to do with graduate courses. Assuming that a course with, say, 5 or 6 students who interact is a much more satisfactory experience than one with 1 or 2 students, we see that the desirable enrolment size is a function of course structure. If there were a programme which did not require courses, this second criterion of size would not apply. But if it is felt that students should take a substantial number of courses (as appears to be the case in all the Ontario departments), then the consideration is valid and the situation needs examination.

It appears that some of our departments plan enrolments as small as 6 to 12. It may be that some of these departments, because of specialization, course structure, post-doctoral and master's population and interdepartmental collaboration, offer an academically sound experience for the student, while other departments with the same enrolment may not. Each case needs evaluation separately.

This brings us back again to the desirability of your giving a detailed analysis of each university. We request evaluation of quality by area of study of each department, including an analysis of the kind of intellectual milieu established for a student by the enrolment size.

I hope you realize that we have a problem of reconciling the reports of the consultants on the various engineering disciplines. One report of which there seems to be pretty general approval is that dealing with electrical engineering. Of course not all its details are accepted by everyone, but the style and coverage of the report has not been attacked. I enclose a copy, since it may make clearer what I have been trying to say in this letter.

After you have had a short interval to consider the letter, I shall telephone Professor Meyerhof to discuss the mechanism of your response. We need your assistance.

Yours sincerely,

M. A. Preston

M. A. Preston

MAP/cew
Enclosures.

VII. ELECTRICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the electrical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C20

> It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

Other Discipline Groups might also consider this recommendation.

Recommendation C21

> It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

The work in electrical engineering at Carleton is divided into two departments, Electronics and Materials Engineering which includes solid state device electronics, circuits and circuit theory, microwave electronics and electron beam systems and processes and the Systems Engineering programme which concentrates on information systems such as communications and signal processing, decision and control, digital systems design and software engineering. The coverage within these two areas is well integrated, coordinated and appropriate for PhD training. The enrolment increase proposed by Carleton is within the competence and capability of the present staff.

Recommendation C22

> It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

McMaster has outstanding strength in three areas of graduate research and has plans to strengthen a fourth. These are communications and data processing, modelling and design, materials and devices and, lastly, medical electronics. The electrical engineering programme at McMaster is of high quality, with a productive and dynamic faculty.

Recommendation C23

> It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

The department at Ottawa specializes in three areas, communication systems, control and systems, and computer engineering. With a faculty of 11, the consultants felt that they were spread over a rather large area of electrical engineering. A small department with a small number of staff and students can operate an effective doctoral programme only with competent professors, complementary fields of study and an adequate research environment. The consultants recommend discontinuing the programme. ACAP has considered both the consultants' report and the university's comments and has concluded that Ottawa has a contribution to make to graduate electrical engineering study in operating a specialized programme of limited scope and enrolment.

Recommendation C24

> It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

The areas of specialization at Queen's are communications, systems, electronics, and energy processing. The consultants state that the work in communications is good but is only fair in systems, and that the Department should not offer a programme in the latter two fields on a regular basis. However, we suggest that an occasional student be allowed to do a thesis in one of these fields. ACAP accepts the consultants' view about enrolment which was made on academic grounds, not for planning reasons.

Recommendation C25

> It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

Graduate work at the University of Toronto covers seven areas including communications, computers, control, power devices and systems, solid state electronics, wave sciences, and biomedical electronics. The coverage of these fields is more than adequate and Toronto's "star-studded" faculty are spread over the seven areas indicating significant breadth across the department. The consultants conclude that the Toronto department compares favourably with any of the major institutions in North America.

Recommendation C26

> It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

The University of Waterloo concentrates in five major areas including computers and communications; control, systems and networks; devices, circuits and materials; power engineering; and, antennas and electromagnetic engineering. There are two minor fields, bioengineering and electroacoustics, and these fields should be limited in size to the present level of activity. With Waterloo's highly competent faculty and well-equipped facilities, there is no question that the enrolment level planned by Waterloo can be accommodated.

VIII. MECHANICAL ENGINEERING

There are a number of general recommendations and comments made in the mechanical engineering consultants' report that are aimed at the system as a whole. Recommendations for the individual universities follow this more general section.

The mechanical engineering consultants do not anticipate any oversupply of mechanical engineers. They believe no "artificial edict" is necessary to control the number of PhDs. On the contrary, they suggest the problem will be one of availability of good students. The consultants think that Ontario might, in fact, have a shortage of mechanical engineers.

"Traditional classical" versus "applied" research projects and a shift in emphasis of study are the next problems attacked by the consultants. They feel that the doctoral education of today should shift more towards project and design activity. To this end, they advocate increased dialogue and cooperation with outside agencies such as industry and government. "If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front". The consultants also recommend a change in emphasis in fields of study. Some areas of research that need to be developed are listed on page A-14.

The consultants do not condone departments that attempt to be good in all fields. They feel specialization is the key and that "considerable selectivity is required in the choice of a particular area of concentrated effort". This choice of areas of concentration should be left up to the universities. ACAP agrees with this outlook but notes that the initiatives of each department in Ontario are matters for collective consideration and advice. ACAP advises the departments to consider the consultants' suggestions noted in the addendum and asks that they report on progress made after a year of mature consideration. After this time, the Discipline Group, in its normal role, would continue to consider the development of new areas of graduate study and the possible entry into neglected fields in mechanical engineering in Ontario and would make recommendations to ACAP where change is desirable.

Another problem the mechanical engineering consultants addressed was the one of faculty age. Since the Ontario universities have been through an expansionary period in the sixties, a large proportion of the faculty is below 45 years old, consequently lacking something in maturity and industrial experience. The consultants feel that although the retirements in the next several years will be few, the universities should take these opportunities to introduce new blood by appointing faculty with industrial experience.

It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendations

Recommendation C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

The Mechanical Engineering consultants, in their addendum, give valuable suggestions for focussing research activities in each department. These suggestions appear to be based on both planning grounds and grounds of academic quality, but alternative research foci may not be ruled out. Consequently, ACAP recommends that the three doctoral programmes continue but that each university note the consultants' comments and report on progress in a year's time.

Recommendation C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

The consultants, in their remarks concerning the University of Ottawa, page A-17, recommend that the work in the Mechanical Engineering Department be incorporated in an interdisciplinary programme leading to an undesignated PhD degree. ACAP notes the university response, page C-14, which states that they wish to "reactivate" the doctoral programme, before discussion of this new proposal. We do not at this time make a recommendation on the future form of engineering PhD work at the University of Ottawa. There appear to be no planning reasons why there should not be a programme at Ottawa in mechanical engineering, but the consultants have serious reservations about the suitability of a number of the research projects of the department and about the limited industrial experience of its staff members.

Recommendation C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

We draw the attention of the University of Toronto to the consultants' suggestion that the Department of Mechanical Engineering concentrate research on problems of major, national concern. UTIAS should note the consultants' comments on the need for selectivity within the broad spectrum of the expertise of the staff, in such areas as plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. The consultants also favour increased interaction with work in related fields on the main campus.

Recommendation C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

ACAP notes the consultants' suggestion that the department concentrate in Production and Automation. We also take note of Waterloo's response which lists strengths in other areas. We recommend that Waterloo consider the consultants' idea of developing foci of research interest and report on any action thought desirable.

The University of Western Ontario and the University of Windsor have not been discussed here, since there is no need for any recommendations in addition to those in the section on University Recommendations, page 20.

IX. METALLURGICAL AND MATERIALS ENGINEERING

This section of the ACAP report will deal with the recommendations found in the metallurgical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C31

> It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these reommendations.

The consultants find it surprising that there is so little effort in the ceramics and glasses fields of study. Even more striking to them is the absence of any work in polymers in the Departments of Metallurgy and Materials Engineering. In their first few recommendations, they consider it very important to rectify these neglected areas and ACAP feels this is a job for the Discipline Group. They also feel it is important to strengthen already existing areas of study and in particular create at least one internationally-known centre of materials science activity.

Recommendation C32

> It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:
>
> a. recruitment of students with physics and chemistry backgrounds
>
> b. strengthening of the extractive metallurgy faculty
>
> c. collaboration with Toronto

The materials science programme at McMaster is considered by the consultants to be the best programme of this kind in Ontario and probably in Canada. It is the only programme that covers adequately the basic science related to all classes of materials including polymers. The enrolment could be easily doubled without developing the need for any significant increase in resources allocated to the programme, but enrolment, here, is limited as in so many other areas of engineering, by the number of qualified students.

The extractive metallurgy programme, although not as strong as the materials science one, provides very suitable research for the doctoral thesis. The range of the programme is, however, inadequate but cooperation with other McMaster Departments and with the University of Toronto will greatly enhance the operation of this programme.

ACAP suggests that McMaster consider the points put forward by the consultants and that the university report to ACAP on any action taken with regard to these recommendations.

Recommendation C33

> It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975 if a favourable appraisal is not obtained.

The consultants consider the programme in physical metallurgy at Queen's a good, traditional type of programme taught by young and talented faculty. Although it would make a suitable base on which to build a programme in materials engineering, the consultants do not recommend that Queen's do so.

The programme in extractive metallurgy, on the other hand, is not so well off. It is seen by the consultants to be inadequate in its present form, with too small a range of courses, too limited an amount of research activity, and ineffective interactions with other departments and programmes. But the consultants feel it is necessary to strengthen and develop this field, to provide the needed PhD graduates and maintain Queen's part in a history of leadership in Canada in mineral engineering, geology and related fields.

The enlarged programme of extractive metallurgy is envisaged by the consultants to consist of support from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology. ACAP realizes that cooperation cannot be legislated, but it must have some formal structure in order to make the various professors aware of their part in a cooperative venture and secure the recognition of their departments for the effort devoted to the venture.

Recommendation C34

> It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975 on any progress made in this direction.

Toronto has an international reputation for its graduate work in extractive metallurgy. However, the range of courses is limited; this situation could

be improved through cooperation with McMaster. The consultants feel this would provide a good base from which to develop a programme in mineral engineering and extractive metallurgy and they advise the university to do so.

In addition to those who work in extractive metallurgy there is another group of professors in the department who describe their work as physical metallurgy and materials research. These people working with added specialists in polymers and electrical and optical properties of materials would form a group capable of mounting a substantial programme in materials engineering.

Recommendation C35

> It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Waterloo has no specific programme in materials and does not offer a PhD labelled as metallurgical engineering or any allied field. Instead, students are trained in extractive metallurgy in the Department of Chemical Engineering and there is a group of metallurgists and materials scientists in the Mechanical Engineering department. The consultants felt their effort was of such high quality that if this group were constituted as an administrative unit, they would be the strongest and most comprehensive graduate programme in materials engineering in the province. The consultants recommend setting up a separate administrative structure. However, the unit (all in one department) appears to function well without separate administration and ACAP does not feel that such a structure is imperative. Waterloo will, no doubt, consider the consultants' suggestion.

X. MINING ENGINEERING

Queen's University offers the PhD in mining engineering. This is unique in the province. Although the enrolment is small, the programme appears to fill a distinct need. The University projects no enrolment increase, showing only 4 students in 1977-78.

On the basis of the statement of future plans made by the University, we recommend:

Recommendation C36

> It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

XI. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

This section of the ACAP report will deal with the recommendations found in the industrial engineering and systems design consultants' report. It will contain recommendations on the Universities of Toronto and Waterloo. ACAP suggests that the University of Windsor take careful note of the recommendations made in this consultants' report but at this time ACAP makes no specific recommendations on doctoral work in industrial engineering at Windsor since it is part of the earlier Recommendation C11.

The general recommendations in this report echo many of those found in the earlier consultants' reports. These consultants' estimates of manpower supply and demand closely follow those made by the other consultants and are discussed more fully in the second part of this ACAP report. Related to this is the need to increase the Canadian content in engineering programmes. Recommendations C1 and C3 refer specifically to these two points.

ACAP notes that the universities do not consider the establishment of a co-ordinating committee to be very important. We hope that talks are normally taking place between the three departments and that they will continue. ACAP feels there is no need to set up a formal Discipline Group to ensure discussions but if those concerned wish to do so it can be arranged.

Again, as in the other consultants' reports there is seen to be a need to circulate information to the student concerning the various programmes in order to ensure he selects the programme best suited to his objectives. This problem has been addressed by Recommendation C7.

ACAP endorses the consultants' recommendations 6,7,8,9 and 11 and does not wish to make any particular comments on these recommendations.

Recommendation C37

> It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

In its response to the consultants' report, the University of Toronto seems in general agreement with the recommendations made concerning its programme. ACAP notes that the Department has already made the appointment suggested in recommendation 3.

As far as future enrolment is concerned, ACAP suggests the university continue to expect approximately the same enrolment as it now enjoys. In accordance with standard appraisal procedures, a shift in fields of specialization to programmes in health systems and energy systems would require referral to the Appraisals Committee to determine whether or not an appraisal is necessary.

A review of the enrolment expectations would be made at that time. For the present, a continued output of 3 or 4 PhDs a year should be expected by the university. This should not be regarded as a quota but rather as the outcome of the present situation of fewer qualified students and falling enrolments. It should be noted that the University of Toronto has maintained a high percentage of Canadians in its industrial engineering programme in comparison to other engineering programmes both in the University of Toronto and elsewhere.

Recommendation C38

> It is recommended that the University of Waterloo continue its doctoral programme in systems design.

ACAP takes note of the response of the University of Waterloo to the consultants' various recommendations concerning the Department's isolation, its "soft" course content and the quality of recent staff appointees. Despite the possibility that enrolments may increase in this field and despite the comments from the University, ACAP considers that Waterloo should give careful attention to the consultants' recommendations for strengthening the programme before increasing the enrolment.

APPENDIX A

Council of Ontario Universities

Advisory Committee on Academic Planning

Ph.D. Planning Assessment

in

Industrial Engineering

Report

of the

Consultants

Albert G. Holzman

Lotfi A. Zadeh

Acknowledgments

The consultants wish to express their appreciation to Professor M. A. Preston, who established the guidelines for the study and who briefed the consultants prior to the actual visitations at the three universities in Waterloo, Toronto, and Windsor. The data and information prepared by Miss Susan Cale were very helpful in the assessment study and the consultants are grateful for her assistance.

Unfortunately, it is not possible to recognize individually here the many administrators, faculty, and students who were so gracious to us, but most significantly, responded so freely and candidly to the many questions, often quite sensitive and critical, that the consultants raised during their visitations. Without their cooperation and assistance it would have been impossible for the consultants to generate a meaningful report. The consultants are most thankful to all of them.

Table of Contents

Salient Terms of Reference and Procedure of Consultants

1. Special study was to be conducted for ACAP of Ph.D. work in Industrial Engineering at Toronto and Windsor, and Systems Design at Waterloo.

2. Two consultants were chosen by ACAP from a list by the universities involved: Dr. Albert G. Holzman, Professor of Industrial Engineering at the University of Pittsburgh, and Dr. Lotfi A. Zadeh, Professor of Electrical Engineering and Computer Sciences at the University of California in Berkeley.

3. No discipline group was involved in the study.

4. The consultants spent one day at each of the three universities: December 18, 1973, at Waterloo, December 19, 1973, at Toronto, and January 3, 1974, at Windsor.

5. The consultants' terms of reference were similar to those in the engineering planning assessments.

6. The consultants were asked to comment on the current and proposed program in Management Sciences at Waterloo, discussing its nature, quality, and relation with the program in Systems Design. During the visitation at Waterloo the consultants requested the opportunity to meet with faculty in Management Science. The meeting could not be arranged because of tightness of schedule.

A briefing was held for the consultants by Professor M. A. Preston on the evening of December 17, 1973, in the office of the Advisory Committee on Academic Planning (Ontario Council on Graduate Studies). Prior to this meeting the consultants received the following information for review:

1. Procedure and terms of reference for consultants

2. Terms of reference of consultants - Chemical Engineering

3. Ontario Council on Graduate Studies, By-Law No. 3

At this meeting Dr. Preston distributed the following materials to provide an information base.

1. Industrial Engineering Doctoral Planning Assessments prepared for Toronto and Waterloo. These are essentially data bases. It is important to note that these were prepared in 1972-73, and there may be discrepancies with 1973-74 data.

2. Ring of Iron - A study of Engineering Education in Ontario - December 1970.

3. Statement by the Council on Ontario Universities and Responses by Committee of Ontario Deans of Engineering, Ontario Council on Graduate Studies, and Association of Professional Engineers of the Province of Ontario to Ring of Iron: A Study of Engineering Education in Ontario.

4. Supply and Demand for Engineering Doctorates in Canada, Canadian Engineering Manpower Council, July 1973.

5. Ph.D. Planning Assessment in Chemical Engineering - Report of the Consultants, 1973.

6. Report on Chemistry, 1973.

Before the visitation at Windsor, the consultants received a copy of the Industrial Engineering Doctoral Planning Assessment for Windsor, and also its "Statement of 5 Year Plan as Projected for ACAP Doctoral Planning Assessment (1973-1978)." The consultants were instructed by Dr. Preston to request the 5 year planning statement while visiting Toronto and Waterloo, since they were to have been prepared. They were informed during their visitation, however, that these planning statements were not available.

In addition to the above data bases, the consultants received bulletins, brochures, technical reports, publications, and other material to help them in the assessment of the doctoral programs.

Probably most importantly, the information and data received from administration, faculty, and students in the course of the many discussions held during the three-day period, enabled the consultants to obtain the pulse and feel the tenor of the major thrusts of the programs under review. It must be recognized, however, that in verbal communication the possibility for misinterpretation and misunderstanding does exist. With this qualification, the consultants hope that the following report is objective, fair and accurate.

1. Overall Introduction

1.1 Evolution and Development of Industrial Engineering

Industrial Engineering is relatively new as a profession when compared with the more traditional areas such as chemical, electrical, and mechanical engineering. Even though the first degree program in industrial engineering was offered in 1908, the official society for industrial engineers, the American Institute of Industrial Engineers (AIIE) was formed in 1948. Industrial Engineering departments have been conceived in various academic environments, and while emphasis may vary from school to school, the following definition prepared by AIIE in the late fifties indicates its broad interdisciplinary people-oriented, and systems character.

"Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems."

The character and sophistication of Industrial Engineering have changed dramatically since the classical time and motion study work of F.W. Taylor and F. B. Gilbreth in the early 1900's. The "efficiency expert" who emerged in the 1930's used the basic techniques of time study and methods engineering; in fact, the major focus of academic programs and industrial assignments in IE up until 1950 was on the fundamental methods engineering and work measurement activities developed by the IE pioneers. However, extensions into plant layout, production planning and control, and job evaluation had taken place in the thirties and forties. Most of the academic programs at that time terminated at the bachelor's level, though a few universities did have master's programs especially for evening students located in an industrial environment.

Even though the Industrial Engineering curriculum usually contained the same basic engineering, science, and math courses as in other engineering curricula, the level of mathematics required for the IE courses was freshman algebra and geometry.

This was the setting that the IE academician found himself in the fifties when linear programming, probability and statistics, computers, and simulation began to emerge as formidable tools for solving complex problems. The aspiring and ambitious IE academician, in an attempt to gain respectability among his colleagues, was quick to grasp these techniques and include them in the IE curricula. These were sophisticated, analytical, and relatively new to other engineers. At that juncture, doctoral programs began to develop in Industrial Engineering and eventually they became attractive not only to students in Industrial Engineering per se, but also to students with other engineering and science backgrounds.

Later, the idea of the systems approach became popular and it, too, was embraced by the Industrial Engineers, It should be noted that in the fifties and sixties not all IE departments were able to lay first claim to some of these new concentration areas and some were absorbed by other departments. While the profile of IE up until 1950 was quite standard, the diverse thrusts of IE departments in the following two decades have made it difficult to give a specific identity to IE. In the United States this resulted in the use of joint names to define a department - such as Industrial Engineering and Operations Research, Industrial Engineering and Systems Engineering, Industrial and Operations Engineering, Industrial Engineering and Management Sciences.

Even though the "classical" industrial engineers were involved in measurement of human performance, in the past two decades there has been renewed interest in this area but now with the focus on human factors, which includes physiology, ergonomics, engineering psychology, and performance prediction.

As a result of the interdisciplinary activities of the IE in the past 20 years, the Industrial Engineer has been able to contribute to the solution of a broad spectrum of problems in manufacturing, business, government, and service type activities, and the job horizon expanded greatly for people with this type of training.

1.2 Industrial Engineering in Ontario and Canada

In the Province of Ontario only two Industrial Engineering Departments are in existence--one at the University of Toronto (formed in 1958), and the other at the University of Windsor (commenced in 1972). At the University of Waterloo, the program in Systems Design was included in this doctoral assessment, as requested by ACAP. It must be pointed out that the faculty in the Systems Design Department do not wish this Department to be considered an IE Department. However, the two major thrusts of the Systems Design Department--human factors and physical systems--are directly related to industrial engineering as broadly interpreted today.

Also, at the University of Waterloo, the graduate course of study in Management Sciences is relevant to industrial engineering, but this program was not within the purview of these consultants.

Based on intensive one-day visitations at each of the three schools included in this study, the consultants feel that each department has its own distinctive character, and a significant need does exist for their graduates in educational institutions, industry, government, and service organizations in the Province of Ontario and other provinces of Canada.

At Waterloo the major emphasis is on human factors (physiology and ergonomics) and physical systems; at Toronto the concentration areas are human factors (engineering psychology), information systems, and operations research; and at Windsor the thrusts are in man-machine systems and production systems. Certainly the consultants recognized some duplication in the programs and do urge a close, cooperative relationship among the three schools to maintain their distinction.

Outside the Province of Ontario industrial engineering studies are available at the Nova Scotia Technical College, École Polytechnic in Montreal, University of Newfoundland, University of Quebec, and the University of Moncton in New Brunswick.

1.3 The Demand for Industrial Engineers

Since Industrial Engineering education in the United States has had a several decade lead time on Canada in this profession, it is desirable to depict the employment trend of industrial engineers in the States over the past two decades. The following table shows that employed industrial engineers in the U.S. increased by approximately 100% each decade.

Year	Employed IE's
1950	40,140
1960	96,053
1970	185,389

Source: The Bureau of Census' Occupation by Industry

The American Institute of Industrial Engineers (AIIE), which is also the professional society for industrial engineers in Canada, recently conducted a sample survey of its members to ascertain the transition of IE employment from manufacturing to non-manufacturing industries. While the following table indicates that manufacturing is still the major employer of all industrial engineers, a substantial number are now employed in the government and service type activities.

	Employed IE's Surveyed	
Industry	1966	1971
Manufacturing	82%	59%
Government	3%	7%
Education	5%	4%
Construction	6%	9%
Finance, Real Estate, Wholesale and Retail Trade, Transportation, Professional Services	4%	21%

At the doctorate level the per cent of graduates is much higher in the non-manufacturing and service type activities than in manufacturing, and the graduate is frequently employed in a department or division not called industrial engineering. For example, of the total 22 Ph.D. graduates from Industrial Engineering at the University of Toronto since its inception, 15 were employed in the academic field in a wide variety of concentration areas such as business, management sciences, environmental design, and mathematics, as well as industrial engineering. Those employed in the non-academic environment also exhibited a breadth of assignments, such as systems research, social development, educational planning, hydro and petroleum companies. It is also significant to note that of these 22 Ph.D. graduates, 13 were employed in the Province of Ontario and 5 in other provinces of Canada.

Thus far 5 students have received their Ph.D. from the Systems Design Department of Waterloo and similarly, their employment is in diffuse areas of concentration. At Windsor no doctorates have been granted as yet by the IE Department.

Since no other schools in Canada offer the Ph.D. in IE, it appears that less than 20 people in Canada have received their doctorates in IE from a Canadian university.

While employment of Ph.D.'s in academic institutions is "drying up," nevertheless, at least 5 staff positions in industrial engineering are presently open in Canadian universities.

Since the opportunities for IE and Systems Design doctoral graduates cover such a broad spectrum of activities, it is almost impossible to forecast with an acceptable level of confidence the actual demand for these graduates in the next 5 years. However, based on past experience and departmental projections over this period, the output from the system will not be great: approximately 3-4 per year from Waterloo, the same number from Toronto, and 1-2 per year from Windsor. On the average for this period, about 7 per year will be the total Ph.D. output in IE and Systems Design.

Based on previous data and discussion, the consultants feel that the actual demand will be higher than this supply over the next 5 year period, recognizing that only two schools in Canada offer a Ph.D. in IE. With the exception of Windsor, the present support level at both Waterloo and Toronto could increase their doctorate enrollment by 10-15%. However, the limiting constraint is the number of well qualified applicants for Ph.D. work in these areas.

It is also appropriate to point out that at the November 1973 meeting of the Committee of Deans of Engineering of the Province of Ontario, at which time there was a report on the status of engineering Ph.D. graduates during the period November 1972-October 1973, the overall conclusion was "that there is still no serious unemployment among recent Ontario Ph.D. graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established."

2.0 Overall Recommendations

1. The Ph.D. programs in Industrial Engineering at Toronto and Windsor, and the Ph.D. in Systems Design at Waterloo continue so that the demand for graduates - bachelors, masters and doctorates in the Province of Ontario and Canada, be satisfied by quality programs matched to these needs.

   While the demand for Ph.D. graduates is small relative to the number of employment opportunities for undergraduates, nevertheless, it must be realized that to have a prestigious undergraduate program does require a quality faculty. Without a doctorate program it is not possible to attract faculty who can teach new and sophisticated methods to the undergraduate student. The result would be a serious weakening of the undergraduate program.

2. The Ph.D. programs in IE at Toronto and Windsor, and the Ph.D. program in Systems Design at Waterloo maintain their distinct character and thrust.

   At Waterloo the major emphasis is on human factors (physiology and ergonomics) and physical systems; at Toronto the concentration areas are human factors (engineering psychology), information systems, and operations research; and at Windsor the thrusts are in man-machine systems and production systems.

3. The quota for Ph.D. output from the three programs be maintained at approximately the same level for the next five years.

   This means 3-4 graduates per year from Waterloo, 3-4 from Toronto, and 1-2 from Windsor. Since these graduates are diffused in a broad spectrum of jobs, a review of the placement of these students indicates a relatively strong market exists for employment. But many of the jobs are outside engineering, and consequently, it is difficult to obtain a reliable projection of the demand 5 years hence. It is the consultants' opinion that it will probably increase rather than decrease.

4. A coordinating committee be established with a representative from each of the three departments.

   A major function of this committee would be to coordinate and plan the development of graduate programs of each department, to avoid excessive duplication of course offerings, and to operate in a cooperative manner rather than in a competitive mode.

5. A counselling structure be developed to insure that Ph.D. applicants are properly advised of the principal strengths in each of the three departments so that the applicant can make an optimal selection of a program to achieve his objectives.

   Due to logistical and personal problems it may not always be possible to locate at a specific university; however, all prospective Ph.D. students for industrial engineering related programs in the Province of Ontario should be cognizant of the type of training to be received and the job market for which their training would prepare them.

6. New faculty appointments be of high quality and inbreeding detrimental to the future development and progress of the departments be discouraged.

This recommendation applies in particular to Waterloo and Windsor where new faculty are likely to be employed. An external review of potential new faculty may be desirable.

7. Additional external research grants be obtained in consonance with the objectives of the respective departments.

While equipment is not usually a major item in IE related research, nevertheless, the research money per faculty member in each department is considerably less than that in other engineering departments. These additional resources would be helpful in the attainment of excellence in the absence of a significant increase in funding from the universities - recognizing that the "tight money" situation is likely to continue for the next 5 years in higher education.

8. A more significant role of Industrial Engineering and Systems Design be effected in other departments both within and outside engineering.

Faculty in IE-related departments provide a valuable resource to the total university structure, and while some interaction has already taken place, it has not been sufficiently exploited.

9. A cognizance and strategy for implementing research in the real world socio-political environment be a salient consideration in the Ph.D. programs.

This is not meant to imply that theoretical, abstract reasearch is not desirable; however, most of the graduates will be operating in a complex systems structure that demands realistic solutions to problems and this must be reflected in the academic preparation of the student for employment.

10. A recruiting effort be made to stimulate a larger population of highly qualified Canadians to apply for Ph.D. work in Industrial Engineering and Systems Design.

With these fields being relatively new, many graduates from other engineering departments are not cognizant of the concentration areas and the employment opportunities for the Ph.D. graduate from these departments. The recommendation is not to encourage higher enrollment, but to provide a larger base for student selection into the programs.

11. An attempt be made to recruit qualified women for Ph.D. study in Industrial Engineering and Systems Design.

During the discussions which the consultants had with doctoral students in the programs not one woman was present. In the United States a greater number of women (still not large) are entering these programs and do have excellent job opportunities after graduation.

University of Toronto
Department of Industrial Engineering

3.1 Overview of Consultants' Activity

Both ACAP consultants spent one day, December 19, 1973, at the University of Toronto to review and obtain information for the engineering assessment study of the Ph.D. program in Industrial Engineering.

The original schedule prepared for the consultants, visitation included a general discussion of the Industrial Engineering program, separate meetings with faculty in each of the three major concentration areas of the Department (Human Factors, Management Information Systems, and Operations Research), and a meeting with the Dean of Graduate Studies. The consultants requested the opportunity to meet with the present Dean and the immediate past Dean of the Faculty of Applied Science and Engineering, and also with students enrolled in the doctoral program. Those additions to the original agenda were made and scheduled appropriately.

While one day is not much time to spend in an assessment study, nevertheless, the meetings were intensive and comprehensive, and the consultants feel that they have obtained an adequate factual basis for judging the Industrial Engineering program.

University of Toronto
Department of Industrial Engineering

3.2 Agenda for ACAP Consultants' Visit (December 19, 1973)

9:00 - 10:50 a.m.	Consultants - Dr. A. Holzman and Dr. L. Zadeh met with B. Bernholtz, P. J. Foley and J. G.C. Templeton for a general discussion in Room 204A
10.00 a.m.	COFFEE
10:50 - 11:20 a.m.	HUMAN FACTORS - P. J. Foley and consultants toured labs.
11:20 - 12:15 a.m.	MANAGEMENT INFORMATION SYSTEMS - B. Bernholtz S. H. Cohn I. B. Turksen R. W. P. Anderson Discussion with Consultants in Room 204A
12:20 - 1:00 p.m.	DEAN ETKIN (Present Dean at his office)
12:30 - 2:00 p.m.	LUNCH - Small Dining Room - FACULTY CLUB Consultants and Staff Members - J. W. Abrams J. Abrham R. W. P. Anderson B. Bernholtz J. Buzacott S. H. Cohn A. A. Cunningham P. J. Foley T. A. Lambe J. S. Rogers J. G. C. Templeton I. B. Turksen
2:15 - 2:45 p.m.	Dr. James Ham (Dean, 1966-1973) Discussion with Consultants in Room 204A
2:45 - 3:45 p.m.	OPERATIONAL RESEARCH - J. W. Abrams B. Bernholtz J. Templeton J. Buzacott T. Lambe A. A. Cunningham J. S. Rogers

3:45 - 4:20 p.m. GRADUATE STUDENTS - discussion with Consultants in Room 204A

Ph.D. Students
- Eric Pickett
- Russ Brown
- Percy Brill
- Marvin Mandelbaum
- Duncan Taylor
- Jean Belle-Isle
- Sushil Gupta
- Michael Silberstein (M.A.Sc. student)

4:35 - 5:00 p.m. Dean Safarian - Dean of School of Graduate Studies (and Professor of Economics)
Dean Scott - Associate Dean, Division III, SGS (and Professor of Physics)
Discussion with Consultants and B. Bernholtz in SGS Office.

PROFESSORIAL STAFF NOT PRESENT

A. Porter, Professor and Chairman of Department
A. Kruger, (part-time Professor, by cross-appointment from Department of Political Economy)
J. Senders, (Visiting Professor)
M. Posner, (Associate Professor)

REGISTERED Ph.D. STUDENTS (who did not meet with the consultants)

J. Brandejs
D. Martell
B. Rao
R. Buie
D. Ellis
A. Jenkins

University of Toronto
Department of Industrial Engineering

3.3 Overall Perspective

To obtain the necessary insight and perspective of the doctoral program at Toronto, it is desirable to place it in the context of the Department's development, and its bachelor's and master's curricula. The Department is an outgrowth of the program in engineering and business which was started in 1949, and administered by the Mechanical Engineering Department. Due to the dissatisfaction with qualitative emphasis and concomitant absence of analytical thrust, this program was phased out in 1958 and the Industrial Engineering Department was initiated at that time. Graduate Study in the Department commenced in 1961, and the first Ph.D. was awarded in 1965. Dr. Arthur Porter, who had been Dean of Engineering at the University of Saskatchewan was appointed Chairman of the IE Department. He was succeeded by Dr. Ben Bernholtz in 1966 and then reappointed Chairman again in 1973.

Until 1966 the University of Toronto had the only IE Department in Canada and as of the present time it is one of two universities in Canada where a Ph.D. can be obtained in Industrial Engineering. In the Province of Ontario, the University of Windsor presently has a bachelor's program, a master's program and a doctoral program in Industrial Engineering. At the University of Waterloo the closest programs to IE are those in Management Sciences and Systems Design. The Management Sciences Department is strictly a graduate program, whereas the Systems Design Department has both undergraduate and graduate programs culminating with the Ph.D.

Relative to the Systems Design Department at Waterloo and the IE Department at Windsor, the IE Department at Toronto has a much longer history and has grown substantially in stature during the past 10 years. The program is sufficiently flexible to permit the doctoral candidate to do research in both theoretical and applied complex systems problems relevant to the societal needs of Canada.

The consultants consider the three concentration areas consisting of human factors engineering, management information systems, and operations research to be desirable thrusts for the Department.

Generally, the quality of the faculty is reasonably good and more than adequate for supervising doctoral research. A cursory review of doctoral theses was made when the consultants visited Toronto, and it is our impression that this work is of acceptable quality.

The need is urgent for a regular appointment of the second faculty member (currently visiting professor) in the human factors stem. Identity of the information systems group in Industrial Engineering has not been recognized sufficiently in the Faculty of Applied Science and Engineering. Their role should be clearly delineated and a strategy to project the IE Department as leaders in this activity should be developed. The consultants feel that additional strength is

needed in this area - possibly at the expense of the Operations Research group when feasible to shift resources.

Based on the consultants' discussion with 7 doctoral candidates, they are well prepared and were able to articulate their research interests and objectives quite well. The selection process for doctoral students seems to be effective in the identification of quality students for the program. The consultants do express some concern about the total elapsed time to obtain the Ph.D.

The physical facilities in human factors engineering are excellent and do provide a valuable resource not only to other components of the University, but also to industry and government in the Province of Ontario.

All of the 22 students who graduated with the Ph.D. in IE since the start of the doctoral program had no difficulty in obtaining jobs. Considering the broad interdisciplinary type of activities for which the doctoral graduate is prepared to address not only in industry, but also in public service and non-manufacturing functions, the demand for people with this training is expected to increase within the next 5 years.

Dean B. Etkin gave a strong endorsement of Industrial Engineering by placing it high on his priority list for additional resources, but it must be recognized that additional funding will have to come from shifting resources and this will be difficult.

An assessment of the IE Department's strengths and weaknesses is given in detail in the following sections, followed by specific recommendations in Section 3.8.

University of Toronto
Department of Industrial Engineering

3.4 Nature of Programs Offered

It is significant to note that due to the relatively recent origin of Industrial Engineering at Toronto, the Department has not been plagued with a faculty polarized on one side by classical, traditional IE concepts, such as time study, methods, etc., and on the other side by the more modern approach structured at Toronto which integrates probability and statistics, computer science, operations research, human factors, information systems, and control theory. This discipline focuses on the operation and management of industrial and service type industries. The faculty at Toronto are attuned to the more sophisticated man-machine systems approach in obtaining solutions to real world problems.

The undergraduate curriculum is a four-year program, and it is the terminal degree for most of the students. This program does permit the student to take a meaningful sequence of technical electives in the second, third, and fourth years. The third and fourth years of the IE curriculum include courses directly related to human factors, management information systems, and operations research, which are the major concentrations at the Ph.D. level.

The Department offers two master's degree programs: (1) the Master of Applied Science designed for the student wishing to conduct research, and (2) the Master of Engineering program structured primarily for the student who is presently employed in industry, government, or business, and who desires to become more proficient in modern technical skills addressed to design, analysis, and control.

The M.A.Sc. program is particularly demanding of faculty time for research supervision, and entrance into this program is more competitive than admission into the M. Eng. program. The usual path to the Ph.D. program is through the M.A.Sc. research oriented degree, though it is possible for qualified M.Eng. graduates to be admitted to the Ph.D. by taking an additional year's work.

Students in the M.A.Sc. program and the M.Eng. program must elect an area of concentration in either Operations Research or Information Systems. With the addition of a second faculty member in Human Factors Engineering, it is planned that an M.A.Sc. thrust in this area will be available to students in 1974-75. These three concentration areas are the same as the major thrusts of the faculty at the doctoral level.

The IE Department is also cooperating with the Mechanical Engineering Department and the Metallurgy and Materials Science Department in a new M.Eng.

program for students; it is a program for students from industry.

The Master of Engineering programs take less time to complete and are oriented to the Canadian market.

To be admitted into the 2-year Ph.D. program, the Graduate Student Handbook of the Department of Industrial Engineering states that "an applicant must have completed the requirements for the degree of Master of Applied Science in the Department of Industrial Engineering, or its equivalent, and demonstrated an ability to pursue independent and scholarly research at a sufficiently advanced level. Those completing a research degree elsewhere must submit sufficient evidence of their ability to study at the doctoral level."

For those students who have completed the M.Eng. program or where uncertainty exists in the appraisal of transfers, they may be elegible for a three-year doctoral program. An important aspect of the admissions process is that the applicant must obtain the formal commitment from the faculty member of the IE Department expressing his willingness to supervise the student's research.

In addition to satisfactory completion of the dissertation, the major requirement in the Ph.D. program, each candidate must complete at least one course in the Department of Industrial Engineering for each of five topics in the student's area of concentration. For Operations Research the core area topics are: Mathematical Programming, Stochastic Models, Decision Theory, Systems Simulation, and Information Systems. For Information Systems the core area topics are: Management Information Systems, Stochastic Models and/or Mathematical Programming, Decision Theory, System Simulation, and Production and Control. The Human Factors core area will be developed within the next year and will also be available to doctoral students. Other courses deemed necessary by the supervisor to perform the thesis research must also be taken.

No qualifying or comprehensive examinations are required of the doctoral candidates; the major examination is the oral exam for the thesis. Two external members must be included on the thesis examining committee. Early in the doctoral student's program (within 15 months) the supervisor and the department chairman meet to assess the research activities of the candidate. The student may be terminated at this time if it is considered unlikely that he can satisfactorily complete the research necessary for the degree.

University of Toronto
Department of Industrial Engineering

3.5 Faculty Quality and Size

The number of faculty increased from 12 in 1968-69 to 16 in 1973-74. Of the total number of 16, one member has a cross-appointment with the Department of Political Economy, and another is a visiting professor. The latter faculty member is expected to be given a regular appointment to the IE faculty at Toronto next year as a result of obtaining additional support from the Dean for the concentration area in Human Factors Engineering.

Twelve of the faculty have their Ph.D. degrees; their educational background was obtained from a wide spectrum of prestigious schools, with only two receiving their degrees from the same university. There is reasonably good balance among the faculty ranks: 6 are professors, 6 associate professors, and 4 assistant professors. The average age of the faculty is 44, with the range from 31-63. While this may be considered to be slightly on the high side, the age spread does provide a reasonable balance of maturity which is customarily associated with a well-established department.

Nine of the faculty are currently supervising doctoral students in their research with the largest number supervised by any one faculty member being 5. While a uniform ratio of doctoral research advising among faculty is not expected, nevertheless, this disparity in research supervision is too great. In the three concentration areas of the Department the current research areas of the students can be categorized as follows:

Human Factors Engineering	- 1 student
Management Information Systems	- 5 students
Operations Research	- 12 students

These numbers roughly approximate the faculty concentration in each of the areas. It should be noted, however, that at present Human Factors is not a concentration area for doctoral students, but it will be within the next year.

According to data received from the Dean's Office, the Engineering School's budget for sponsored research in 1972-73 was 4 million dollars, of which $57,000 was in the Industrial Engineering Department. This represents approximately $4,000/faculty member in the IE Department, as compared with $6,000/faculty member in Civil Engineering and $21,000/faculty member in Electrical Engineering. This low amount in sponsored research was discussed in detail with faculty members from the Operations Research group.

They opinionated that large amounts of sponsored research money from other departments in engineering is used for purchasing laboratory equipment, whereas in Industrial Engineering very little sponsored research money was used

or needed for equipment, since most of their laboratories are in real world settings. The exception to this would be the Human Factors laboratory in IE which does require considerable equipment for which additional funds have been obtained from the Dean during the past year. It was also pointed out that the IE grants committee for NRC has been in existence only for the past three years. Also, some of the IE faculty members are on joint research projects in other departments.

Since all faculty at the University of Toronto are paid from University funds on a 12-month basis, and since all good students are able to obtain adequate support funds, it was argued that the present level of sponsored research is close to optimal for the Department. Apparently, there is no incentive to obtain additional sponsored research. All faculty are on a three-term appointment and teach only two of the three terms. The third term can be used for research, publications, supervising theses, and other types of professional development.

Despite the justification offered for the existing level of external funds for research, the consultants do consider the present funding for sponsored research to be on the low side. For example, through research grants it would be possible to purchase additional equipment for the human factors laboratory. It also may be possible to provide a higher stipend for doctoral students as research assistants or associates, and thus incite them to continue full time in their program, rather than to obtain full time non-university employment and complete their dissertation on a part-time basis, as is frequently the case.

The three major concentration areas of the faculty will now be reviewed.

Human Factors Engineering

While the doctoral students will not have a concentration area in Human Factors available for the next year, considerable activity has taken place by the two professors (one currently visiting) in the undergraduate and graduate levels, and also in advising and working with graduate students in other departments, such as electrical engineering, architecture, aerospace, psychology and computer science. This human factors thrust is unique at the University of Toronto and does provide a focal point for this area of activity.

The Systems Design Department at the University of Waterloo has a major thrust in human factors, and while not mutually exclusive with the Toronto activity, the Waterloo emphasis is more on the ergonomic-physiological aspects than that at Toronto where the thrust is more towards engineering psychology.

Professor Foley has done an excellent job in the design of laboratory facilities in human factors. The laboratory facilities can be categorized as: (1) pure research laboratory - basic research to human factors; (2) undergraduate and master's laboratory - demonstration and individual experiments, information processing and acoustics; (3) process control facility; and (4) complex skills

laboratory. This laboratory has also been useful in providing service to the Province of Ontario. As is typical in most industrial engineering departments which do not have machine shops, this laboratory is the only physical laboratory in the Department.

While neither of the faculty in this area have a Ph.D. (one of whom is a Visiting Professor) nevertheless, they have had a wealth of experience in human factors engineering and experimental psychology in industry, government, and education. The two faculty members have contributed substantially to professional organizations and have published in respectable journals; however, the last refereed publication for the one faculty member was in 1965 and the other in 1967. The consultants recognize the desirability that the new appointee have a doctorate, especially since he will be advising Ph.D. students; but they also are aware of the practical need for this faculty person to have had considerable actual experience. The consultants did not have the opportunity to meet the Visiting Professor, but his background does seem to exhibit the qualifications required to guide research concomitant with teaching both undergraduate and graduate level courses. It is important, however, that he focus his publications on refereed journals.

To provide the faculty time necessary to supervise doctoral theses and to publish in addition to teaching at the undergraduate and graduate levels and directing the laboratory, it is important that an additional professor be appointed to a regular faculty position.

Thus far 7 master's students have completed their master's theses in this area. One Ph.D. graduate from Toronto was supervised by the full-time faculty member in Human Factors Engineering.

At the present time in this area there is one research grant (NRC) which is for the amount of $5,000.

It was not obvious that faculty from the Information Systems and Operations Research concentration areas interact on a professional basis with the faculty in the Human Factors area. This apparent insulation of faculty groups is not conducive to the most effective utilization of departmental resources in the man-machine system environment.

Management Information Systems

While this is a separate concentration area for doctoral students in Industrial Engineering, considerable overlap and interaction exists between the 4 faculty members specifically identified with this area and those involved with the Operations Research area. The faculty in information systems does have a reasonably good background in computers, simulation, systems analysis, and statistics, which do relate to their information systems objectives. Two of the faculty have their Ph.D.'s and the other two have the master's degree as their terminal degree.

Current research interests are in the areas of health care delivery systems, medical information systems, computer-communications network, production

systems management, interactive problem solving, structural inference, computer generated aids for the analysis of dimensional relationships, data transformation and data structures, management query languages, and applied Boolean methods.

Some publications from the faculty in this area have appeared recently in refereed journals, but the total publication output of the group in recent years has not been great. Three of the four faculty members have research grants from NRC, ranging from $5,000 - $17,000. There are spikes of excellence in this group, but their overall quality does not seem to be at a uniformly high level. The external visibility and impact of this faculty on other departments at the University of Toronto may be impaired by the fact that information is ubiquitous by its very nature, and is also housed in other departments.

Professor Bernholtz, who is presently on a leave of absence after having served as department chairman, should be able to provide the stimulus necessary to have this group exercise leadership in information systems at the University. He has had considerable experience in working with staff from other divisions at Toronto.

Since information systems spans many disciplines, extreme caution must be taken not to duplicate inordinately courses offered in other areas. Courses such as software technology, file organization and structure, computer systems analysis, and data structure are taken by the Industrial Engineering graduate students in the Electrical Engineering and Computer Science departments.

Overlap does exist to some extent with the Management Sciences Department at Waterloo. However, while both Toronto and Waterloo are involved with health care systems, the work at Toronto is related to the medical school. At Waterloo, there is no medical school.

In the Faculty of Management Studies (similar to a business school) at the University of Toronto, a MBA is offered and a Ph.D. program has been initiated recently. An earlier relationship existed between Industrial Engineering and the Faculty of Management Studies in which there was an exchange of faculty. Unfortunately, this relationship dissipated as the faculty in the management studies program became more quantitative. At the present time an attempt is being made to re-establish the relationship and it is important that the attitude of the two departments be one of cooperativeness rather than competition.

Even though courses in Management Studies such as Business, Information Systems, Planning and Control Systems, Systems Simulation, Decision Theory, and Management Information Systems, may be oriented to the business environment, nevertheless, it is quite possible that considerable duplication exists with similar courses in Industrial Engineering.

However, when a business school with a quantitative emphasis exists in a university with an industrial engineering department it is not uncommon to find

considerable competition and overlap between the two groups.

Operations Research

The greatest faculty effort of the IE Department is in the Operations Research concentration area. Over half of the faculty are involved in this activity of the Department. Due to the commonality of interest and program objectives, significant interaction does take place with the Information Systems faculty, but practically no professional relationship exists with the Human Factors' faculty members. As stated previously, this should be corrected.

All of the faculty have the Ph.D. as their highest degree, and have a reasonable number of publications in refereed journals. Their present research interests encompass a broad band of Operations Research type activities, as is evident from the following sample of projects: non-linear and continuous programming, implementation of OR, reliability, inventory systems, decision theory, scheduling with uncertainty, urban transportation systems, stochastic models, and generation planning. Every faculty member has a sponsored research project from NRC, ranging in amount from $1,500 to $20,000. A need exists to have post-doctoral fellows and research associates to interact with and further challenge the faculty to continue to advance their research competence.

Again, an appraisal should be made for possible duplication of courses in the quantitative stem of the Management Studies program at Toronto where related courses such as the following are offered: integer and nonlinear programming, stochastic methods, network flows, and statistical decision theory. The Management Science Department at Waterloo also has an OR thrust.

The faculty felt that unusual opportunities were provided to the doctoral student interested in OR at Toronto by the balance between theoretical and applied work, the unique data base for hospital studies, and the interaction with other departments at the University of Toronto. They also expressed the desire to have post-doctoral fellows and research associates.

In summary, the overall quality of the faculty does seem to be reasonably good, but there is a need to shift resources in the Department, when possible, to achieve a better faculty balance which is required to meet the objectives of the Department in a more effective manner and at the same time produce a greater impact on the total University structure. The addition of a second faculty member in human factors engineering is a requisite.

University of Toronto
Department of Industrial Engineering

3.6 Quality of Student Body: Admission Requirements

The ACAP consultants met with nine of the doctoral candidates, with no faculty present, to discuss the Ph.D. program in Industrial Engineering with them. The prime consideration in the admissions process for the Ph.D. in this Department is evidence of research capability of the applicant. An A- average in graduate courses and an A on the thesis is required of all students who have completed the M.A.Sc. program in Industrial Engineering at Toronto. Those students who have completed the M.Eng. curriculum are accepted only in exceptional cases. Good quality students from other branches of engineering, mathematics, or science, may also be admitted to the graduate programs. Approximately 85-90% of all IE graduate students have an engineering background. Prerequisites for graduate work demand a level of mathematical maturity equivalent to a substantial knowledge of calculus and differential equations, probability theory and statistics, and also a knowledge of computer programming. Applicants who have received their master's degrees outside the IE Department at Toronto are required to submit their theses for evaluation by the faculty. If the candidate has not prepared a thesis, he may be admitted directly to the Ph.D. program, or as is the usual case, be accepted in the M.A.Sc. program with possible transfer to the Ph.D. program.

Figure 1 shows the acceptance-rejection status of Ph.D. applicants for 1973-74. Of the 24 students who applied, 19 were accepted into the graduate program of study, and 5 were rejected. It is of interest to note that of the 19 students accepted only 7 students actually registered in the Fall Term.

University of Toronto
Department of Industrial Engineering

Summary of

Ph.D. Applications 1973-74

1. Accepted Ph.D. applicants -- Registered

   5 (of whom 2 had completed M.A.Sc. programs in this Department)

2. Accepted Ph.D. applicants -- Did not register

   5
   1 - expected in January 1974

3. Ph.D. applicants accepted into M.A.Sc. -- Registered

   2

4. Ph.D. applicants accepted into M.A.Sc. -- Did not register

   4
   1 - expected in January 1974

5. Ph.D. applicants accepted into M.Eng. -- Did not register

   1

6. Ph.D. applicants -- Refused

   5

Note: Eleven students completed M.A.Sc. program in 1972 and seven in 1973. Some of these were not interested in the Ph.D. program. Others wished to do Ph.D.'s, but were refused, or discouraged from applying. We have no record of the number in each of these groups.

Figure 1

For each of the current Ph.D. candidates, Figure 2 lists the student's previous degrees, fields, and graduation dates from the universities attended.

The students interviewed felt that the strongest points of the doctoral program were its flexibility and degree of freedom, good counselling, and faculty strength in many areas. They had frequent consultations with their faculty supervisors. The candidates were articulate in explaining why they had enrolled at the University of Toronto, and they also were quite clear and precise in expressing their areas of research interests. One of the graduate students was working on his Ph.D. in Electrical Engineering, but had selected an area of concentration in Human Factors Engineering from the IE Department. He considered the courses that he has taken in this area to be meaningful and constructive and evaluated the faculty highly.

In reviewing the research interests of several of the doctoral candidates, it was evident that they were attuned to the strengths and interests of the faculty and were concerned with real world problem solutions. This is evident from the listing of research areas and dissertation titles for Ph.D. candidates 1973-74 shown in Figure 3.

Twenty-two students received their Ph.D. degrees from 1965-1973, and all were placed without difficulty. Fifteen of the graduates entered the academic field in a wide variety of concentration areas such as business, management sciences, environmental design, mathematics, industrial engineering, etc. Those employed in the non-academic environment exhibited similar breadth of assignments. At least eighteen are now working in Canada, 2 in India and 1 in Singapore.

University of Toronto
Department of Industrial Engineering

Ph.D. Candidates
1973-74

Name	Previous Degrees	Field	University and Year
Belle-Isle, J.	B.Sc.	Mathematics	Montreal, 1966
	M.Sc.	Computer Science	Montreal, 1970
Brandejs, J. F.	Ing. C.	Commerce	Prague, 1947
	C.Sc.	Computer Science	Prague, 1967
Brill, P. H.	B. Sc.	Mathematics	Carleton, 1957
	M.A.	Mathematical Statistics	Columbia, 1959
Buie, R. N.	B.Sc.	Mathematics	Guelph, 1970
	M.A.Sc.	Industrial Engineering	Toronto, 1971
Ellis, D. W. H.	B.Sc.	Mathematics	Queen's, 1968
	M.Sc.	Mathematics	Queen's, 1970
	M.B.A.	Business	York, 1973
Frances, D.	B.A.Sc.	Industrial Engineering	Toronto, 1970
	M.A.Sc.	Industrial Engineering	Toronto, 1972
Gupta, S.K.	B.Tech.	Mechanical Engineering	Indian Institute of Technology, Bombay, 1967
	M.B.A.	Business	Delhi, 1969
	M.A.Sc.	Industrial Engineering	Toronto, 1973
Jenkins, A. L.	B.A.	Natural Sciences	Oxford, 1963
	M.A.	Natural Sciences	Oxford, 1968
	Diploma	Management	McGill, 1972
Lau, H.	B.Eng.	Electrical Engineering	McGill, 1969
	M.Eng.	Electrical Engineering	McGill, 1970

Figure 2

Ph.D. Candidates - 1973-74

Name	Previous Degrees	Field	University & Year
Lieberman, R. W.	B.A.Sc.	Industrial Engineering	Toronto, 1971
	M.A.Sc.	Industrial Engineering	Toronto, 1973
Mandelbaum, M.	B.A.Sc.	Industrial Engineering	Toronto, 1964
	M.Sc.	Operational Research	Israel Institute of Technology, 1968
Martell, D.	B.A.Sc.	Industrial Engineering	Toronto, 1971
	M.A.Sc.	Industrial Engineering	Toronto, 1972
Pickett, E. E.	B.A.Sc.	Mechanical Engineering	Toronto, 1957
	M.A.	Mathematics	Toronto, 1962
Rao, V.N.	B.Tech.	Electrical Engineering	Indian Institute of Technology, Madras, 1964
	Dip.	Business Administration	Ahmedabad, 1967
	M.A.Sc.	Industrial Engineering	Toronto, 1970
Taylor, I.D.S.	B.A.	Mathematics	Sussex, 1969
	M.Sc.	Mathematics	Toronto, 1970

Figure 2 (Continued)

University of Toronto
Department of Industrial Engineering

Ph.D. Candidates 1973-74

Name	Research Area or Dissertation Title	Supervisor
Aerath, S.	Boolean Method and Scheduling (R.A.)	I. B. Turksen
Bastien, E.	The Effect of Transportation Distance on Consumer Choice (D.T.)	T. A. Lambe
Belle-Isle, J.	Design methodologies for cost-effective, application-oriented Computer/Communications Networks (R.A.)	S. H. Cohn
Brandejs, J.F.	Some Theoretical and Practical Aspects of Medical Information Systems for Ambulatory Health Care (D.T.)	S. H. Cohn
Brill, P. H.	Multiple Server Queues with Service Time Dependent on Waiting Time (R.A.)	M. J. M. Posner
Bule, R. N.	Continuous Programming (R.A.)	J. Abrham
Ellis, D. W.	Routing Problems (R.A.)	A. A. Cunningham
Frances, D.	Data Acquisition for Linear Programming Problems (D.T.)	A. A. Cunningham
Gupta, S.K.	Applied Boolean Methods in Production Scheduling (R.A.)	I. B. Turksen
Jenkins, A. L.	Operations Research in Transportation (R.A.)	A. A. Cunningham
Lau, H.	Application of Optimal Control Theory to a Canadian Econometric Model (D.T.)	J. Abrham
Lieberman, R. W.	Design of Information Systems in Health Care Delivery (R.A.)	I. B. Turksen
Mandelbaum, M.	Policy Flexibility and Facilities Planning (D.T.)	A. A. Cunningham

Figure 3

Name	Research Area or Dissertation Title	Supervisor
Martell, D. L.	Contribution to Decision Making in Forest Fire Management (D.T.)	A. A. Cunningham
Pickett, E. E.	Mathematical Modelling of Biological Processes in Lakes (D.T.)	B. Bernholtz
Rao, V. N.	Statistical Pattern Recognition with Incorrect Data (D.T.)	J. G. C. Templeton
Strong, D.	Computer-aided Pattern Recognition of Three Dimensional Solid Objects (D.T.)	P. J. Foley
Taylor, I. D. S.	Decision Models for an Emergency Ambulance System (D.T.)	J. G. C. Templeton

NOTE: R. A. = Research Area
D. T. = Dissertation Title

Figure 3 (Continued)

From the data in Figure 4 on number of doctoral students registered for the four-year period the following salient points can be stated:

(1) The total enrollment has not changed significantly.

(2) 44 of the 75 students (58.6%) were Canadians and 23 of the 78 (30.6%) were landed immigrants.

(3) Of the total 75 students, 43 (57.3%) received their 1st degree in Canada, and the remaining 32 (42.7%) obtained their 1st degree from a foreign school.

(4) Approximately one-half of the Canadian students are full-time in the doctoral program, whereas for the landed immigrant and student visa status, almost all of these students are full-time.

From Figure 4 we can also see that on the average 4 students receive their Ph.D. each year, and that very few of the doctoral students are dropped from the program. This does mean that most of the students are in the program considerably longer than the 2-3 years required for a full-time student. The number of elapsed months to obtain a degree is depicted in Figure 5. Of the total of 13 students who received their doctoral degrees over the past 4 years, no one completed the requirements in less than 36 months, and only 4 in less than 48 months. The reason cited by the faculty for this long time to completion was that the doctoral student often receives attractive employment offers while doctorate work is in progress, and that frequently the job assignment is related to the dissertation research of the candidate. There seems to be no strong incentive to complete the degree in 2-3 years. Heavy course concentration is at the master's level, with emphasis on research for the doctorate.

Concern was expressed by the consultants on the elapsed time in the program to obtain the doctorate: it was felt that students may be past their peak in training when the degree is granted. Due to the fact that the major examination for the doctoral candidate is the oral exam on the completed dissertation, the faculty indicated that the student had to maintain a state-of-the-art status of his particular research area to have his dissertation approved. The student's supervisor has the responsibility to insure that the student is currently abreast of his field. External examiners on the committee also serve to ensure that the research is of high quality and current. However, it is important that these characteristics be evaluated carefully in making final judgment on the student's thesis.

Financial support for graduate students does seem to be adequate with aid coming from a broad spectrum of sources. One of the most prestigious scholarships is the NRC Scholarship, of which there are four holders.

The consultant's impressions of the doctoral students may be summarized by the following statements.

Number of Doctoral Students Registered

in Industrial Engineering 1969-73

Immigration Status	1969-70 Country of 1st deg.		1970-71 Country of 1st deg.		1971-72 Country of 1st deg.		1972-73 Country of 1st deg.		Totals
	Canada	Foreign	Canada	Foreign	Canada	Foreign	Canada	Foreign	
Canadian FT	6	1	4	--	4	--	5	--	20
PT	5	--	8	1	6	1	3	--	24
Landed immigrant FT	--	3	1	5	1	4	--	6	20
PT	--	--	--	2	--	--	--	1	3
Student Visa FT	--	2	--	--	--	2	--	2	6
PT	--	--	--	--	--	--	--	--	0
Other FT	--	--	--	1	--	1	--	--	2
PT	--	--	--	--	--	--	--	--	0
Totals	11	6	13	9	11	8	8	9	75

Doctoral Degrees Awarded

1969-70	1970-71	1971-72	1972-73
2	4	5	2

Number of Doctoral Students Dropped-Out

1969-70	1970-71	1971-72	1972-73
1	--	--	1

Figure 4

Industrial Engineering Doctoral Planning Assessment

Time to Reach Degree

Year Degree Granted	Total Elapsed Time in Months					
	< 36	36-43	44-47	48-59	69-72	>72
1972-73	--	--	1	1	--	--
1971-72	--	--	--	2	1	2
1970-71	--	2	--	1	1	--
1969-70	--	1	--	1	--	--
Totals	0	3	1	5	2	2

Figure 5

University of Toronto
Industrial Engineering Department

3.7 Physical Facilities

The Industrial Engineering Department at the University of Toronto is not manufacturing oriented and thus does not have the large machines that are in some IE departmental laboratories. There is no need for this heavy equipment, considering the thrust of the Department at Toronto.

The facilities in the human factors laboratory are excellent - having a total value of approximately $150,000. It includes a Hewlett-Packard Recording System (7858-A, 7878-A), a Texas Instruments 960-A Computer and Peripherals, a PDP-11 computer and an EAI-TR-20 analog facility.

The University of Toronto Computer Centre facilities are available for course work and research of faculty and students. This digital computer configureation does seem to be reasonably adequate for the demands of the IE Department.

University of Toronto
Department of Industrial Engineering

3.8 Recommendations

1. Develop a meaningful integration of the Information Systems and Operations Research groups with the Human Factors Component. It is natural for the first two groups to relate to each other since they have similar educational experiences, but it is much more difficult to bring together behavioural-psychological faculty with the systems-OR type people.

2. Emphasize in the doctoral program research related to real world problems. With the "drying-up" of the academic market for new faculty, placement of the doctorates will be in industry, government, and service type activities. The existing program structure, with a strong methodological base and concomitant opportunity for applications, does permit a student to design doctoral program structure attuned to real world needs.

3. Appoint an additional full time faculty member in Human Factors Engineering to permit a concentration in this area at the doctoral level. The laboratory and instruction are valuable not only to doctoral students in Industrial Engineering, but also to students in other departments in the Faculty of Applied Science and Engineering and in other programs at the University of Toronto.

4. Provide incentive for more Canadians to continue as full time students in their doctoral programs. Approximately one-half of the Canadians in the IE doctoral program have employment in industry and government. This extends greatly the time to obtain the doctorate, with most of the students requiring 4-6 years to graduate.

5. Focus research and educational objectives of the Human Factors stem on the engineering psychology thrust in contrast to the physiological emphasis in the Systems Design Department at the University of Waterloo. At the present time this difference is cited, but should be clearly delineated, especially with new faculty members to be added in this area in both universities. It is feasible at the expense of travel time that doctoral students from one school may elect to take courses from the other school to achieve the balance desired in his doctoral program structure.

6. Stimulate faculty to obtain additional support from external sources so that funds will be available to achieve excellence in the absence of any additional funding from the University. With a budget in the next several years expected only to reflect cost of living and merit increases, it will be essential to obtain funds from outside sources if the program is to continue to progress, maintain high quality standards, and achieve excellence.

7. Establish a rapport with the Faculty of Management Studies to avoid inordinate duplication of courses in Information Systems and Operations

Research. Effective allocation of resources, especially in a tight money situation, is important to obtain the goals and objectives of the University. With the information of a quantitative structure in Management Studies, an attitude and working relationship of cooperation rather than competition must be generated.

8. Develop an awareness and potential strategies for implementing research in the real world environment. Experts in sophisticated analytical methods and mathematical model building are often criticized for their inability to have their tools and techniques accepted and applied.

9. Structure a more significant role of Industrial Engineering in the other engineering departments relative to systems involving the dynamics of man-machine interaction. While indeed some interaction has already taken place, the IE Department should take a leadership role in the man-machine systems of engineering. It is recognized that other departments also concentrate on the systems approach, but with different objectives.

10. Develop an identity in information systems which will clearly delineate its function and will serve as a nucleus and catalyst for this activity throughout the University. Information structures, data files, storage and retrieval, feedback and controls - are ubiquitous throughout a large university and do require a definition of the activity profiles to be subsumed under various departments and schools. The expertise of IE faculty in computers, systems design and analysis, man-machine interaction, and optimization does suggest that they assume a significant role in this area.

11. Design an organizational mechanism at the graduate level which will provide bridges and an environment for Ph.D. studies and research for interdisciplinary type activity. While it is recognized that the IE Department is involved in interdisciplinary type of activity, a need exists at the University level for greater coordination and facility in the generation and development of projects which tend to take on a university-wide perspective. As an example, at the University over 45 projects are active in health care delivery systems.

University of Windsor
Department of Industrial Engineering

4.1 Overview of Consultants' Activity

The University of Windsor campus was visited by the consultants on January 3, 1974. The discussions that ensued and the information requested were aimed primarily to provide both a factual and a descriptive basis for the assessment of the doctoral program in Industrial Engineering.

The original agenda included a meeting with the President of the University, Dr. J. F. Leddy; the Dean of Graduate Studies, Dr. C. P. Crowley; the Dean of Engineering, Dr. D. J. Kennedy; the Department Head, Professor C. L. Proctor, faculty from the Industrial Engineering Department and related faculty from Electrical Engineering, the Director of the Computer Center, Mr. L. F. Miernicke, and the Director of Central Shops, Mr. Brudy.

In addition, the Vice-President of the University, Dr. F. A. DeMarco, joined the consultants for lunch. Due to the time constraint, the consultants elected to forego inspections of the University Library and the Electronic Research Shop.

As in the visits to Waterloo and Toronto, the day spent in Windsor was crowded with discussions with the Administration, faculty and students, as well as inspections of the laboratory facilities. Despite the shortness of the visit, the consultants feel that they have obtained an adequate factual basis for providing an assessment of the doctoral program in IE at Windsor and for commenting on the quality of faculty and students who are involved in it.

University of Windsor
Department of Industrial Engineering

4.2 Agenda for ACAP Consultants' Visit (January 3, 1974)

Approximate Time	
9:00 a.m. - 9:30 a.m.	Orientation Meeting with Department Head - Dr. Proctor
9:30 a.m. - 9:45 a.m.	Faculty Lounge (Meet Faculty)
9:45 a.m. - 10:00 a.m.	Coffee (Faculty Lounge)
10:00 a.m. - 10:30 a.m.	Dr. J. F. Leddy - President
10:30 a.m. - 11:00 a.m.	Dr. A. Raouf (Man-Machine Systems)/Professor Eley (Industrial Liaison)
11:00 a.m. - 11:30 a.m.	Dr. C. P. Crowley - Dean of Graduate Studies/ Dr. D. J. Kennedy - Dean of Engineering
11:30 a.m. - 12:00 noon	Dr. H. Elayat (Applied Operations Research)/ Professor A. Danish (Engineering Economics)
12:00 noon - 1:30 p.m.	Lunch
1:30 p.m. - 2:00 p.m.	Dr. W. M. Hancock - Adjunct Professor of Industrial Engineering (University of Michigan full time)
2:00 p.m. - 2:30 p.m.	Meeting with IE Graduate Students - R. Ghattos - D. McKenzie - R. Patil - B. Singh - Y. Wang
2:30 p.m. - 3:00 p.m.	Dr. W. C. Miller (Systems Simulation)/Dr. M. Shridhar (Computer Aided Design/Stochastic Processes)
3:00 p.m. - 3:45 p.m.	Industrial Engineering Research Laboratories Dr. A. Raouf; Computer Center - Mr. F. Miernicke; Systems Laboratory - Dr. W. C. Miller and Dr. M. Shridhar; Central Research Shop - Mr. Brudy
3:45 p.m. - 4:30 p.m.	Dr. D. J. Kennedy - Dean of Engineering/ Department Chairman; Dr. C. L. Proctor - Head of Industrial Engineering

University of Windsor
Department of Industrial Engineering

4.3 Overall Perspective

As has been true for many industrial engineering departments in the United States, industrial engineering at the University of Windsor was initiated as an option in mechanical engineering. The bachelor's curriculum was introduced in 1966, and the master's and Ph.D. programs in 1967, under the aegis of the Mechanical Engineering Department.

The proposal for a Department of Industrial Engineering, separate from Mechanical Engineering, was approved in 1968, but was not implemented until 1972, at which time Dr. C. L. Proctor was appointed as Head of the Department. The program was approved by OCGS on the basis that this was not a new area of study since it had existed as an option in Mechanical Engineering; as a result, an appraisal of the doctorate program was not made by the Appraisals Committee of the Ontario Council on Graduate Studies.

In retrospect, it is easy to criticize the faculty selection procedure and the planning process employed prior to the formation of IE as a separate department. But what must be considered at this juncture is that the IE Department is in existence; a substantial number of students are enrolled currently in the bachelor's, master's, and Ph.D. programs; the instructional programs are attuned to the requirements of the region and its graduates are in strong demand; and last, but not least important, the Industrial Engineering Department has a high priority status for additional resources from Dr. J. F. Leddy, President of the University, and Dr. D. J. Kennedy, Dean of the Faculty of Engineering.

Dr. Leddy felt that the IE Department could and should assume a leadership role in the University of Windsor's relationship with business and industry. In his view, IE plays an important role as a coordinating group, and there is a strong need for IE's with doctoral training in R&D and consulting activities. Dr. Kennedy expressed his strong desire to have a Ph.D. program in IE to complement the other engineering curricula, and indicated a willingness to make every effort to provide additional funding for the support of Departmental activities.

If the Industrial Engineering Department at Windsor is to meet the objectives and aspirations of the Department and the Faculty of Engineering, a doctoral program is a requisite. Without a Ph.D. program, the Department will not be able to attract or maintain quality faculty or to attract external support for stimulating research projects. Even an undergraduate program is enriched substantially by faculty involved in Ph.D. courses and research. In the absence of a doctoral program, both the bachelor's and master's curricula would be weakened to a point where they will have little appeal to prospective students.

The consultants believe that the formation of the Systems Division in the Faculty of Engineering is a move in the right direction, since it provides an operational medium for Industrial Engineering and Electrical Engineering to cross-list courses and share research and laboratory equipment. This division has been in existence for one year and has already resulted in obtaining funds from NRC for additional computer power and in joint teaching of one course. This relationship between IE and EE, while in its infancy at the present, should contribute to the "critical capability" required to offer a doctoral program.

In summary, the consultants accept the argument for a doctoral program in IE at Windsor and recommend that it be supported at a level sufficient to attract quality students and carry them through their graduate studies. This will require the addition of at least one, and preferably two, well qualified faculty capable of teaching and directing research at the Ph.D. level.

This recommendation for additional funding is actually quite conservative when viewed in the light of the substantial contribution that the IE Department can make to the educational process and public service in the Province of Ontario, and the fact that the University of Toronto is the only other school in the Province with an Industrial Engineering Department.

A more detailed evaluation of the Department's strengths and weaknesses are contained in the following sections. The consultants' recommendations are given in Section 4.8.

University of Windsor
Department of Industrial Engineering

4.4 Nature of Programs Offered

Since the doctoral program is an integral part of the total educational spectrum of the IE Department and must be considered together with the under-graduate and master's programs, a brief presentation will be made of their salient features and characteristics before a more detailed discussion of the Ph.D. curriculum is offered.

The academic programs are more production, mission-oriented than those at the University of Toronto and are focused to satisfy the demands of the region. The undergraduate student enters the IE program in the third year, after having completed two years of engineering at the University. The first two years provide the basic science and engineering foundation, with the latter two years devoted to man-machine operating systems -- which includes coventional Industrial Engineering, such as work management and analysis, plant flow analysis, engineering economy, data processing, operations research, and systems engineering.

The following three divisions were established by the Faculty of Engineering for the purpose of coordinating graduate studies within the Faculty: Engineering Process Design, Structures, and Systems. The IE and EE departmental course offerings constitute, with the exception of one course in traffic engineering, the entire Systems Division structure. The objective of this division organization is to make more effective utilization of available resources and to stimulate interaction among departments in the Faculty of Engineering. The consultants consider this to be a desirable objective to achieve, especially since the number of faculty in any one department at Windsor is relatively small. This divisional structure was initiated in 1972 and the impact on graduate education in Industrial Engineering has not been significant as yet. Due to the involvement of industrial engineers in environmental types of problems, in the future the IE Department should also formally interact with the Engineering Process Design Division.

In contrast to the Systems Design program at Waterloo and the Industrial Engineering program at Toronto, where both Master of Engineering and Master of Applied Science programs are available, only a Master of Applied Science curriculum is available at Windsor. However, the Master of Applied Science degree at Windsor permits the student to elect a non-thesis option as well as a research thesis, and thus does tend to encompass both the M. Eng. and M. Applied Science of the other two institutions.

To be admitted to the Ph.D. program in IE at Windsor the applicant must have at least a Master's Degree in Applied Science, Engineering, or Pure Science. A minimum duration of two full years of full-time study beyond the

M.A.Sc. or its equivalent is required. As is true in many Canadian universities, the major emphasis is on the research for the thesis and formal course requirements are quite minimal. When a student initially registers in the Ph.D. course of study, a research advisor and two additional members are appointed by the Department Chairman to provide the planning and direction of the student's program of study. The Ph.D. student is required to take a minimum of 8 semester hours of course credit beyond the Master's level, and is also expected to attend all of the Department's graduate seminars. After approximately one year in the doctorate program, the student is required to submit his research proposal for approval by his committee.

After completion of all formal course work the student must satisfactorily complete a comprehensive examination, which may consist of an oral or a written test on general industrial engineering, or must present a seminar on a topic other than the student's major concentration area. Each doctoral student must present his work in a Preliminary Seminar, an Intermediate Seminar, and a Final Seminar on his dissertation research.

None of the Ph.D. students interviewed were advanced sufficiently in the program to give an in-depth presentation of their thesis research; thus, it was not feasible for the consultants to form a detailed view of their research capabilities and interest areas. Identified were such broad areas of interest as human factors, industrial labor safety problems, systems engineering, materials science, and operations research/reliability. Clearly, a high level of competence on the part of the faculty supervising the theses of these students is essential to the viability of the Ph.D. program.

University of Windsor
Department of Industrial Engineering

4.5 Faculty Quality and Size

The faculty of the Department of Industrial Engineering comprises four full-time members of the professorial staff: Professor C. L. Proctor (Head); Associate Professor A. Raouf; Associate Professor A. A. Danish; and Associate Professor N. G. Eley. In addition, Lecturer H. Elayat is serving as a temporary replacement for Professor A. Danish while he is on sabbatical leave at Virginia Polytechnic and State University, and Dr. W. M. Hancock of Michigan has a nominal title of Adjunct Professor. At present, only two professors have tenure.

To view the faculty in a proper perspective, it is important to bear in mind the following facts concerning the history of the Department.

Industrial Engineering was started as an undergraduate option in CE and ME in 1966, and as a graduate program in ME in 1967. As a first step in the initiation of this program, A. Raouf was appointed as an Assistant Professor of Industrial Engineering in 1966, after receiving the M.S.I.E. degree from the University of Toledo. In 1967, A. Danish (M.S.I.E. 1967, Georgia Institute of Technology) was appointed as Assistant Professor, followed by the appointment of N. Eley (M.Eng. 1950, Chrysler Institute of Engineering) as Associate Professor and Director of Industrial Liaison in 1968.

The formation of the Department of Industrial Engineering was approved in 1968, subject to the condition that its implementation would be deferred until Head of the Department is appointed. Thus, Industrial Engineering functioned as a graduate program in ME till 1972, when Professor Charles L. Proctor (Ph.D. 1963, Oklahoma State) was appointed as Professor and Head, Industrial Engineering Department. At that point in time, the graduate IE program in ME (both M.A.Sc. and Ph.D.) was transferred to the new department, with the result that no approval for the initiation of a doctoral program in IE was necessary.

The salient fact is that all but one of the current members of the Department were inherited from the IE program in ME. No new appointments have been made since Dr. Proctor became Head in 1972, because there were no vacancies to be filled.

Judged by the conventional academic criteria, the quality of the faculty is marginal. Two of the members of the faculty do not have the Ph.D. degree or other credentials indicative of significant accomplishments in industry or the academe. On the other hand, the third professor is clearly a man of considerable competence in his field whose activities in teaching, research and professional societies reflect much credit on the Department and give it favorable visibility. Also on the positive side, the fourth professor has an unusually broad background in industrial engineering and has the capability to

teach graduate courses and supervise graduate research.

The qualifications of the faculty look somewhat better if one assumes that the main mission of the Department is to serve the needs of local industry, which is centered on automotive manufacturing and related production activities. In this context, the professors' industrial backgrounds are fairly well matched to the mission of the Department and are commensurate with the Department's intention (see the attached 5-year plan) to stress the specialties of Production Systems and Man-Machine Systems.

It is clear that, with its present faculty, the Department can play only a highly circumscribed role in filling the demand for industrial engineering graduates in Ontario. Nevertheless, it is the feeling of the consultants that, limited as this role may be, it is a useful one, and the Department's efforts to strengthen its programs are worthy of support.

Our discussions with President J. F. Leddy, Vice-President, F. A. DeMarco, Dean P. P. Crowley (Graduate Studies) and Dean D. J. Kennedy (Engineering) left us with the impression that the administration of the University of Windsor is strongly committed to the continuation of the doctoral program in Industrial Engineering and is prepared to assign a high priority to its further development.

To have a doctoral program of acceptable quality does require the addition of at least one well qualified faculty member. It is essential, also, that the Department utilize to the greatest extent possible the resources in faculty and facilities available in other departments both within and outside the Faculty of Engineering. The Department has taken commendable initiatives in this direction by strengthening the cooperation between Industrial Engineering and Electrical Engineering and encouraging the participation of the IE faculty in the Industrial Research Institute. Specifically, the Chairman and two professors from the EE Department are jointly involved in teaching graduate courses in stochastic processes and computer-aided design, as well as in a $57,000 grant from NRC for research in Signal Processing and Systems. However, the relation between IE and the Faculty of Computer Science is not as strong as it might be. The consultants feel that there is considerable room for the strengthening of cooperative ties between IE and Computer Science, as well as in the Engineering Process Design Division, and, to a lesser degree, with the faculty of Business Administration.

University of Windsor
Department of Industrial Engineering

4.6 Quality of Student Body: Admission Requirements

The quality, size and character of the graduate student body within the Department of Industrial Engineering in 1973-74 must be viewed in the perspective of its transition in 1972 from a few graduate students enrolled in the IE program in ME to a still small but growing number of graduate students in the two areas (Production Systems and Man-Machine Systems) which constitute the focus of graduate training and research within the Department.

The growth in the size of the graduate student body since 1968-69 together with the projected size for the years 1974-78 is shown below.

	M.A.Sc.		Ph.D.	
Year	Full-Time	Part-Time	Full-Time	Part-Time
1968-69	1	-	1	-
1969-70	1	-	1	-
1970-71	5	-	1	-
1971-72	5	1	-	-
1972-73	7	3	1	-
1973-74	13	7	4	1
1974-75	14	8	4	1
1975-76	14	8	5	1
1976-77	14	8	5	1
1977-78	14	8	5	1

The sharp increase in the enrollment of both M.A.Sc.'s and Ph.D.'s which took place this year is probably due to the energetic efforts made by Professor Proctor to increase the visibility and improve the quality of the graduate program in Industrial Engineering at Windsor. However, as the projections made by the Department indicate, the size of the graduate student body is likely to remain static in the next five years unless the number of faculty is increased by a substantial margin.

The consultants met with five graduate students: R. Ghattas, B. Singh, Y. T. Wong, D. McKenzie and R. Patil. Of these, three are landed immigrants and two are Canadian citizens. Three are M.A.Sc. candidates intending to go on to the Ph.D. degree and two are working toward the Ph.D. degree.

We tried to ascertain the reasons for the students choice of the IE Department at Windsor for their graduate study, considering the small size of the Department and its lack of an established reputation in its field.

Representative of these reasons are the following.

1. Did not apply to Toronto because the OR program in Toronto is too specialized. Prefer Windsor because it has a social science touch.

2. Main attraction of Windsor is close association with industry and the small number of students and faculty members.

3. The computing facilities at Windsor are excellent.

4. Influenced by Professor Proctor's move to Windsor.

It appears that the main attraction of the graduate program at Windsor is its practical orientation and small size. In addition, we presume--without having hard evidence to support it--that the admission standards at the IE Department at Windsor are lower than those of the IE Department at Toronto and the Systems Design Department at Waterloo. (We requested the Department to provide us with the files of students whose admission to graduate study was denied, but the material could not be assembled in time. The information concerning admissions is shown in Figure 6. Five other students were accepted for admission but did not enrol and another seventeen applied but were rejected. Of the students in all 3 categories, all but 6 have received all or part of their education in Asia).

The diversity of the backgrounds of the students whom we interviewed makes it difficult to provide a meaningful assessment of the quality of the graduate student body. Clearly, the graduate students in the IE Department at Windsor are not of the same caliber as their counterparts at Toronto. Nevertheless, overall impression of the quality of graduate students in IE at Windsor is not unfavorable. The students with whom we came in contact appeared to be alert, strongly motivated and enthusiastic. They are pleased with the environment at Windsor and are satisfied with the opportunities for graduate study and research within the Department.

University of Windsor
Department of Industrial Engineering

PH.D. STUDENTS PRESENTLY ENROLLED

Name	Degrees		Area of Interest
El-Sayed, Abdel Razik (accepted September 1973)	B.Sc.	University of Cairo	Materials Science, I.E.
	M.Sc.	University of Cairo	
Khare, Sudhir Kumar	B.Sc.	Madhav Engineering College, Jiwaji University, Givalior, India	Human Factors
	M.Sc.	University of Kansas	
Patil, Linganagouda (accepted September 1973)	B.Sc.	Karnatak University	Systems Engineering
	M.Sc.	Imperial College, London, England	
Singh, Balbir (accepted September 1973)	B.Sc.	University of Wales	Industrial Labor Safety Problems
	M.Sc.	University of Wales	
Wang, Yang-Tsung (accepted September 1972)	B.Sc.	National Taiwan University	Operations Research/ Reliability
	M.Sc.	University of Oklahoma	

Figure 6

University of Windsor
Department of Industrial Engineering

4.7 Research Support and Physical Facilities

In 1973-74, the total amount of research support in the Department amounted to approximately $45,000 out of a total of $750,000 for the Faculty of Engineering. Of this amount, one professor accounted for $35,000, as shown below:

Granting Agency	Title	Amount
Government of Ontario	Repetitive Hand Motions	$26,000
N.R.C.	Combined Manual and Decision Tasks	$ 4,000
I.O.D.E. Hospital	Hospital Systems	$ 5,000

In addition, two other professors have personal research grants, one a grant of $9,000 from the Post Office to study mail prediction systems, and the other, a grant of $1,700 by the Department of University Affairs to develop standard time data for assembly operations.

Clearly, the distribution of research support among the members of the Department is highly unbalanced, suggesting that the research conducted by some of the faculty members is not of sufficient significance or practical value to merit external support. On the positive side, however, the consultants were favourably impressed by the initiatives taken by Professor Proctor to strengthen the research activities within the Department through cooperation with Electrical Engineering. The joint proposal submitted by him and two EE professors to N.R.C. has resulted in the award of $57,000 toward the acquisition of a Datagen minicomputer for digital signal processing, and is likely to contribute in significant ways both to the instruction and research in signal analysis and related problem areas. Additionally, the members of the Department are participating in the activities of the Industrial Research Institute, which currently receives $350,000 per year in outside support and $50,000 from the government.

Insofar as student support is concerned, it should be noted that of the five Ph.D. students who are currently enrolled, three are teaching assistants, one is a full-time employee of the Computer Center, and one is self-supporting due to his arrival after the award of the grants. It appears that the availability of financial support for graduate students does not present a problem at present, and is not likely to become one in the future.

The Departmental laboratory facilities are quite modest in relation to those at Toronto and Waterloo. They consist, in the main, of a Human Performance Laboratory in which a few doctoral students work on problems relating to sorting, unloading of jumbo jets, time and motion studies (using a conveyor belt), etc. The work is supported by the Labor Safety Council and N.R.C.

The computing facilities - which comprise an IBM S/360 together with its peripheral equipment and a small IBM 1620 - are readily available for use by faculty and students and provide excellent service.

In summary, because of its newness and lack of an established reputation in its field, almost all of the students applying for admission to the Department are foreign (mostly Asian), with widely varying educational backgrounds and uneven in quality. The average level, however, is not low and the morale of the student body as well as their degree of satisfaction with the instruction which they receive appears to be high.

University of Windsor
Department of Industrial Engineering

4.8 Recommendations

1. Continue the doctoral program, but not on high-priority basis. It would be unrealistic and wasteful of the limited resources which the Department has at its disposal to attempt to build up a doctoral program that can compete, even remotely, with those at Toronto and Waterloo. The aim should be to have a small-scale program which complements those at Toronto and Waterloo and emphasizes production, mission-oriented type training which fits the needs of the region.

2. Draw on the resources of other departments for instruction and laboratory facilities. In the present climate of austerity and retrenchment, the Department cannot expect to be able to expand its size and facilities even if its graduate enrollment goes up by a substantial margin. Thus, whenever possible, the Department should enter into cooperative arrangements with other departments, especially Electrical Engineering and Computer Science, to make use of their facilities and faculty resources.

3. Make a concerted effort to obtain more research and facilities support from both government and industry. The current level of external research support within the Department is quite low and unevenly distributed. Every possible effort should be made to obtain donations of equipment from industry to upgrade the Human Performance Laboratory.

4. Raise the standards of appointment and advancement of faculty. The small size of the faculty and its uneven quality make it essential that new appointments and advancements be made with utmost care. Vacancies should be widely advertised, and inbreeding should be avoided.

5. Allocate a new position to be filled on a temporary basis. At present, the number of full-time faculty members (4) is too small in relation to the totality of the responsibilities of the Department in teaching and research. On the other hand, considering the scarcity of new positions in the University, the allocation of a full-time position to the Department would be hard to justify at this juncture. Under the circumstances, a temporary addition to the faculty would be a reasonable compromise, with the understanding that, eventually, the temporary position would be converted to a regular full-time one.

University of Waterloo
Department of Systems Design

5.1 Overview of Consultants' Activity

The consultants spent one day - December 18, 1973 at the University of Waterloo, in the course of which they met with the Dean of Graduate Studies, Dr. L. A. K. Watt; the Dean of Engineering, Dr. A. N. Sherbourne; the Associate Dean, T. A. Brzustowski; and the faculty and students in the Department of Systems Design. The consultants also inspected the laboratory facilities and the Computer Center. There was no opportunity, however, to have discussions with members of the faculty of the Department of Management Sciences. Thus, the views expressed in Section 5.8 concerning the interrelation between Systems Design and Management Sciences are based largely on the discussions with Dean Sherbourne, together with the Report to ACAP on the Department of Management Sciences which was made available to the consultants by Dr. M. A. Preston.

University of Waterloo
Department of Systems Design

5.2 Agenda for ACAP Consultants' Visit (December 18, 1973)

9.30 a.m.	Dean L. A. K. Watt, Graduate Studies Dean's Office, NH3024, Ira Needles Hall
10.00 a.m.	Dean A. N. Sherbourne, Associate Dean T. A. Brzustowski Dean's Office, Faculty of Engineering, Room E4.4301A
10.45 a.m.	Coffee with Graduate Studies Committee of Department of Systems Design - Profs. T. M. Fraser, P. H. Roe, B. L. Wills, and Dean Sherbourne (by invitation) Room 3330, Engineering II (Chairman's Office)
11.45 a.m.	Leave for Faculty Club
12.00 noon	Lunch, Faculty Club Dean Sherbourne, Profs. T. M. Fraser, P. H. Roe
1.00 p.m.	Visit University, Faculty, and departmental facilities
1.30 p.m.	Peripheral Vision Laboratory - graduate students D.S. Kochhar, V. W. Sowa, and Prof. T. M. Fraser
2.30 p.m.	Room 1307C. Graduate Students, Y. S. Ho, R. Marrett, R. Divi, and Profs. P. H. Roe, M. Chandrashekar
3.00 p.m.	Coffee, Room 1307C, Faculty members, Department of Systems Design
3.30 p.m.	PDP-9. Graduate Students , K. Andonian, G. J. Savage, R. Maddux, and Profs. B. L. Wills and S. Toida
4.15 p.m.	Room 3330, Engineering II. Graduate students C. Lacombe, C. Nwachuku, Profs. T. M. Fraser, P. H. Roe
5.00 p.m.	Summation

University of Waterloo
Department of Systems Design

5.3 Overall Perspective

The Department of Systems Design at Waterloo is unique not only in terms of its name but also in the character and orientation of its graduate and undergraduate programs. Started in 1965 under the name of Department of Design, it grew out of design groups in Civil Engineering, Mechanical Engineering and Architecture. Its present name and organizational structure date to 1968, when Professor H. K. Kesavan, was appointed as chairman. Since 1972, the Department has been under the chairmanship of Professor T. M. Fraser.

In effect, the Department of Systems Design is an amalgam of several distinct areas of teaching and research, some of which fall within the provinces of Industrial Engineering, Operations Research and Management Science, some within Electrical Engineering, Mechanical Engineering and Aerospace Engineering, and some within Psychology.

The basic question that must be posed and answered is: Is there a raison d'etre for such an amalgam? In the view of these consultants, the answer is in the affirmative for reasons that have local rather than global validity and thus may not apply to other institutions.

Our overall impression is that the Department of Systems Design is comprised of an active, enthusiastic and, in the main, competent group of faculty who have been provided strong support by Dean A. N. Sherbourne and are dedicated to building up a first rate department in terms of its physical facilities, instructional programs and research productivity. The quality of the graduate student body, on the other hand, is rather mixed, and it will probably take some time before it catches up with the quality of the faculty. This, of course, is to be expected in the case of a young department operating in an area that does not fall into an established field of science or engineering.

The demand for the graduates of the Department is strong and is likely to become even stronger in the years ahead, as large-scale systems become more and more complex and the need for specialized training for their design, operation and management becomes more manifest. Thus, the Department will be filling an important need educationally and, in addition, is likely to make significant contributions to system science, management science and human factors through its research in these and related areas.

A more detailed assessment of the Department's strengths and weaknesses is presented in the following section. Our recommendations are proferred in Section 5.9.

University of Waterloo
Department of Systems Design

5.4 Nature of Programs Offered

The programs of study in Systems Design at Waterloo have several distinctive features which lend a unique character to the Department and, on the whole, enhance its attractiveness to both undergraduate and graduate students.

The most important feature, which is shared by all departments in the Faculty of Engineering, is the Co-operative Engineering Program, which is unique in Ontario and, until recently, was unique in Canada. Under this program, which currently has a total enrollment of 4500 (2700 in engineering), all undergraduate students in engineering must go through eight terms of study and six terms of industrial employment to receive the Bachelor's degree. The cooperative M.A.Sc. program is open to all qualified students graduated from Waterloo; it involves 3 academic terms and 3 work terms, adding up to a two year program for the master's degree.

On the Masters level, the student has a choice of three programs:

(a) The Project M.A.Sc., in which the emphasis is on course work (a minimum of eight course units) and in which a research project involving an engineering application or a design problem is a requirement;

(b) The Thesis M.A.Sc., in which only four course units are required and the student is expected to devote a substantial amount of time to his thesis; and

(c) The Cooperative M.A.Sc., in which the student is required to spend three terms in industry or government, acquiring experience in the area of his career interest.

The availability of three alternative programs on the graduate level raises the question of whether or not it is desirable to offer the undergraduate students, too, a choice between the existing cooperative program on the one hand, and a more conventional non-cooperative program which would require only four years for the Bachelor's degree on the other.

Although this issue is, in principle, an important one, it did not fall within the purview of the consultants and hence was not raised in the course of discussions with Dean Sherbourne and other members of the faculty. It will suffice to say that the non-availability of a non-cooperative program on the undergraduate level should not be regarded as an immutable policy for all departments within the Faculty of Engineering.

Another unique feature of the program in Systems Design is the availability of four distinct options on the undergraduate level, each of which is characterized by a set of option core subjects together with a set of technical elective courses.

The options in question are: (a) Computer Systems; (b) Human Systems Engineering and Design; (c) Socio-Economic Systems;and (d) Systems Theory. Together, these options cover almost every conceivable area of specialization with the broad field of Systems Design.

There are no options on the graduate level. Instead, the student is given a choice between three types of programs leading toward the M.A.Sc. degree, as referred to already. In the Project and Co-operative M.A.Sc. programs, the student is required to take at least four from a designated list of six courses, plus four elective courses. In the Thesis M.A.Sc. program, the minimum course requirement is four, with no specific courses other than the Research Seminar required.

A question may be raised concerning the appropriateness of requiring specific courses in the Project and Co-operative M.A.Sc. programs, since the prevalent practice is to give the graduate student nearly complete freedom in the choice of courses, subject only to the approval of a faculty advisor. In this regard, the consultants feel that the somewhat more restrictive policy of the Systems Design Department could be defended on the grounds that the nature of the field of Systems Design is such as to require that the student receive a more than perfunctory training in its major subfields, which center on systems theory, conflict analysis, design principles, human communication and computer-aided design.

The Ph.D. program has no specific course requirements and normally requires about three years to complete. The minimum residence requirement is two calendar years beyond the Master's degree, with five years being the maximum. Each student is required to take a comprehensive examination within a year and not later than 18 months after admission to the Ph.D. program. In a somewhat unusual departure from standard practice, a student who fails the examination may take instead an enlarged course-work program. There is no foreign language requirement.

At present, the Ph.D. program has 11 FTE students of whom only four are Canadian. The Ph.D. program accounts for approximately 10% of the total Departmental effort, compared with 25% for the M.A.Sc. programs and 65% for the undergraduate program.

Apart from several senior undergraduate courses which may be accepted in lieu of graduate courses, the Department offers only nine graduate courses on a regular basis, covering the areas of system modeling, computer-aided design, games, systems theory, decision theories, design morphology and human communications. The catalog descriptions of some of these courses, especially those dealing with Games, Metagames and Rationality (SD631); Applied Metagame Theory (SD632); Design Morphology and Communication (SD668); and Theory of Human Communications (SD671) give the impression of a superficial treatment of vaguely defined topics which are lacking in "hard" content. There are no courses on mathematical programming, optimization techniques, or stochastic systems, presumably because courses in these areas are offered by other departments, especially Management Sciences and Combinatorics and Optimization.

Overall, the consultants' assessment of the graduate programs in the Department is somewhat mixed. On the positive side, the programs are reasonably flexible and offer the student a wide choice of areas for study and research. On the negative side, the Department does not have the necessary resources in faculty or laboratory facilities to offer highly substantive courses on topics which fall within its purview, except, perhaps, in the area of Human Engineering. As a result, many of the graduate courses offered by the Department tend to fall into the "soft" category, and are not likely to be taken by many students in other departments either within or outside the Faculty of Engineering.

University of Waterloo
Department of Systems Design

5.5 Faculty Quality and Size

Judged by the coventional criteria, the quality of the faculty presents a somewhat mixed picture. Of the fifteen full-time members of the Department, seven - which is a rather high number - do not have the PhD degree. However, all seven fall into the category of "older" members (42-65), most of whom were on board when the department was formed. The younger and more recent appointees all have the PhD degree. However, the average age of the faculty is 44 - which is on the high side.

In terms of professional competence and industrial experience, the quality of the faculty is high, but not uniformly so. Some members of the department have extensive and widely diversified backgrounds and high competence in one or more of the fields of study of this multidisciplinary department.

Of the fifteen full-time members of the Department, only five members may be considered to be prominent in their fields. In addition, four others appear to be on the way to achieving recognition. The remaining members have rather meager publication records, due in part, perhaps, to their industrial background and orientation.

All in all, the degree of external visibility of the faculty must be judged to be below par. This does not mean that the faculty is lacking in competence: rather, it is a reflection of the nature of the historical development of the Department and the difficulty of attracting faculty members with established reputations in a field as new as Systems Design.

Given the uneven quality of the earlier appointments to the faculty, the question of whether or not the recent appointments have been of uniformly high quality acquires added importance. The consultants do not have sufficient information on these appointments to offer a definitive judgement. However, the skeletal information provided by the Department does not appear to be particularly reassuring on this score.

In summary, the quality of the faculty presents a somewhat mixed picture, with only about 30% of the staff qualifying to be placed in the "prominent" category. More importantly, the quality of some of the appointments made during the past three years is open to question. Nevertheless, the faculty, on the whole, is competent, active, dedicated and forward-looking. On this basis, the consultants are confident that the Department will grow in stature in the years ahead and will become attractive to outstanding faculty prospects.

The Problem of Inbreeding

It is somewhat disquieting to observe that four out of fifteen faculty members have received all or most of their training at Waterloo, with the most

recent appointee receiving his Ph.D. degree from the Department. This suggests that inbreeding has become a problem that is in need of watching, for it would be highly detrimental to the future of the Department to have a substantial fraction of its faculty comprised of its own graduates.

Research Productivity

Since 1968, the Department has produced 31 Masters and 5 Doctorates, distributed as shown below

1968-69		1969-70		1970-71		1971-72		1972-73	
M.A.Sc.	Ph.D.	M.A.Sc.	Ph.D.	M.A.Sc.	Ph.D.	M.A.Sc.	Ph.D.	M.A.Sc.	Ph.D.
0	0	12	0	4	1	4	1	11	3

The production of both Masters and Doctorates took a jump in 1972-73 and is now about par in relation to the size of the graduate student body: (16 F.T. + 6 P.T.) M.A.Sc. + (11 F.T. + 4 P.T.) Ph.D. (The production of Ph.D.'s is usually about 10% of the number of graduate students.)

The attached table (Figure 7) of research support for departments in the Faculty of Engineering shows the total amount of support from all sources for the Department of Systems Design for 1973-74 to be $62,800, which is quite low in relation to the size of the Department. In this connection, it should be noted that for the Faculty of Engineering (165 FTE + 12 Visiting) the total amount is approximately $5,000,000, which averages to $30,000 per FTE. At this level, the total amount of research support for Systems Design should be of the order of $500,000. The explanation for the much lower figure of $62,800 is that almost all of the research conducted within the Department is of a type that does not require the expensive laboratory equipment that accounts for higher research expenditures in other departments. Still, there is some question as to whether $62,800 is an adequate level of support for a department with fifteen full-time members which is in the process of expanding its programs and increasing the size of its student body.

Discipline backgrounds

Since Systems Design is an amalgam of various disciplines, it is not surprising that the backgrounds of the members of the Department manifest what for a department in an established field would be an unusually wide diversity of patterns of education and industrial experience.

Of the fifteen full-time members, by far the largest group, six in all have their main training in electrical engineering; two have been trained in statistics and operations research; and the remaining seven members have backgrounds ranging from medicine to civil engineering. Despite this diversity, the Department functions well as a unit and appears to be free from factionalism.

UNIVERSITY OF WATERLOO - FACULTY OF ENGINEERING

Summary of Research Grants & Contracts Awarded Fiscal Year April 1/73 to March 31/74 - As At August 15/73
Source of Information: UOFW Res. Grants & Contracts Awarded 1973/74 - N. Stumpf

Chemical Eng.	(Operating	$230,200	$271,667	$16,300	$24,983	$1,400	$314,350
	(Equip.	36,095					
	(Travel	5,372					
Civil Eng.	(Operating	$290,620	299,920	21,500	31,308	28,335	381,063
	(Equip.	8,300					
	(Travel	1,000					
Electrical Eng.	(Operating	$264,500	288,875	3,200	22,786	3,500	318,361
	(Equip.	22,140					
	(Travel	2,235					
Management Sciences	(Operating	$ 67,476	67,476	5,500	-	2,560	75,536
Mechanical Eng.	(Operating	$292,750	368,118	43,025	72,434	44,620	528,197
	(Equip.	62,724					
	(Travel	7,068					
	(Comp.	5,576					
Systems Design	(Operating	$ 53,800	53,800	8,000	1,000	-	62,800
			$1,349,856	$97,525	$152,511	$80,415	$1,680,307
1972/73 Totals:			(1,204,592)	($77,900)	($360,527)	($250,345)	($1,893,364)

(Does not include: Negotiated Development Grants)
(U of W Research Grants)

Figure 7

UNIVERSITY OF WATERLOO - FACULTY OF ENGINEERING

Summary of Research Grants & Contracts Awarded Fiscal Year April 1/73 to March 31/74 - As At August 15/73
Source of Information: UOFW Res. Grants & Contracts Awarded 1973/74 - N. Stumpf

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1972/73 Totals:			(1,204,592)	($77,900)	($360,527)	($250,345)	($1,893,364)

(Does not include: Negotiated Development Grants)
(U of W Research Grants)

Figure 7.

University of Waterloo
Department of Systems Design

5.6 Quality of Student Body:Admission Requirements

The variation in the size of the graduate student body during the period 1968-73 is shown in Figure 8. Allowing for short-term fluctuations, the trend is clearly an upward one. The number of graduate students in 1972-73 ((16 F.T. + 6 P.T.) Masters + (11 F.T. + 4 P.T.) Doctorates) is on the small side in relation to the number of undergraduates (approximately 300 F.T.) However, it is about as large as it can be in relation to the number of faculty members who are capable of supervising graduate research. Furthermore, it is not small in relation to the number of qualified applicants.

According to the information furnished by the Department, about 30% of the applicants are admitted. Of these, approximately 50% are non-Canadian. The proportion of foreign students, although high in absolute terms, is about the same as in most industrial engineering departments in North American institutions. However, what is important about the 50% ratio is that it suggests that the present size of the Department is roughly in balance with the need for graduate training in Systems Design.

In summary, our impressions of the graduate (mainly doctorate) students in Systems Design may be stated as follows:

1. Most of the students have heterogeneous disciplinary backgrounds, some coming from engineering, some from humanities, some from computer science and a few from mathematics. This diversity of backgrounds makes it difficult to enforce high admission standards and maintain a uniformly high level of quality of graduate research within all areas of departmental activity.

2. The quality of graduate students entering the Department appears to be very uneven. Many give the impression of having marginal qualifications, and some are clearly poorly prepared for doctoral research.

3. Without exception, the students are highly pleased with the Department and are enthusiastic about their work. The esprite de corps of the students is, on the whole, very high.

4. The Department is doing what it can to improve the quality of its graduate student body. However, the process is likely to be a slow one, since it takes a long time to raise the reputation of a department to a point where it can attract outstanding students from other, longer-established, institutions.

University of Waterloo
Department of Systems Design

INDUSTRIAL ENGINEERING DOCTORAL PLANNING ASSESSMENTS

POPULATIONS (1)

POPULATION		1968-69	1969-70	1970-71	1971-72	1972-73
FACULTY (2)	F. T.	9	13	15	17	17
	P. T.	1	1	-	-	-
MASTERS STUDENTS (3)	F. T.	16	10	10	16	16
	P. T.	0	6	0	3	6
DOCTORAL STUDENTS	F. T.	7	5	9	7	11
	P. T.	1	3	1	1	4
POST-DOCTORAL FELLOWS		6	1	1	1	2

(1) As of December 1

(2) Includes assistant professors and up. If a faculty member spends time in two divisions, count him once in each. Do not use a percentage. A part-time faculty member is one defined as such by the university at time of appointment. All faculty counted here appear on Form 1 and CV's are included.

(3) This does not include make-up and qualifying year students.

Figure 8

University of Waterloo
Department of Systems Design

5.7 Physical Facilities

By its nature, Systems Design is not a field that calls for extensive laboratory facilities like those of Chemical, Civil, Electrical and Mechanical Engineering. With the exception of human engineering, much of the activity in Systems Design involves system simulation or analytical studies of system behaviour and decision-making. Viewed in this perspective, the laboratory facilities of the Systems Design Department at Waterloo are quite adequate but not outstanding.

The most impressive facility within the Department is the Human Systems Laboratory directed by Professor T. M. Fraser. The principal research activity in this laboratory centers on the Peripheral Vision Project, which includes a dynamic peripheral vision simulator, projection equipment, electronic recording equipment, etc. This equipment is used by Mr. D. Kochhar in connection with his NRC supported research on a mathematical model of peripheral vision. The consultants were very favourably impressed by the Human Systems Laboratory and by the relatively high quality as well as practical relevance of the research conducted within this Laboratory.

In addition to the Human Systems Laboratory, the Department has a Production Engineering Laboratory (directed by P.L. Seeley) which is equipped with a coordinate profiling machine, a TT control computer and supporting instruments. This facility is capable of encoding graphic patterns and producing templates based on programmed modifications to a prototype pattern.

The Department also has access to a PDP-9 facility which is used for research in computer graphics. An Animation Laboratory (directed by D. Schleiermacher) includes an Oxberry animation facility and associated photographic equipment. A Human Engineering Laboratory (under the direction of G. F. Rabideau) is under development and is intended for use in graduate teaching in human engineering.

The extra-departmental facilities comprise, in the main, the University Computing Center, which is among the best on the North American continent; the Engineering Photographic and Graphic Department, which was developed by the Department of Systems Design; and the Engineering Machine Shops, which are well equipped with modern machine tools for electrical and mechanical design and fabrication.

In their totality, the laboratory facilities of the Department of Systems Design are significantly less extensive than those of the IE Department in Toronto but much more impressive than those of the IE Department at Windsor. As stated earlier, the facilities are, on the whole, quite adequate, and in the case of the Human Systems Labotatory, very impressive.

University of Waterloo
Department of Systems Design

5.8 Relation with the Department of Management Sciences

An assessment of the graduate program in Systems Design at Waterloo would be incomplete without an examination of the relation between the Departments of Systems Design and Management Sciences, both of which are in the Faculty of Engineering and thus have to draw on the same source of resources.

The consultants did not have an opportunity to meet Professor D. J. Clough, Chairman of Management Sciences, or have discussions with other members of the MS faculty. The factual basis for the views presented below was provided by the document entitled "A Report to ACAP on the Department of Management Sciences," which describes in great detail the programs of the Department and gives complete information on its faculty. This document was made available to the consultants through the courtesy of Dean A. N. Sherbourne and Dr. M. A. Preston.

The Department of Management Sciences was formed in January 1969 to serve as a focus of graduate training and research within the Faculty of Engineering in a spectrum of areas centering on operations research, applied economics and organizational behaviour. At present, the Department's main concerns are:

1. the pursuit of advanced research in selected fields of the management sciences;
2. the provision of post-graduate courses of instruction; and
3. the provision of undergraduate courses in the management sciences for students in the Faculty of Engineering.

Under the chairmanship of Professor D. J. Clough, the Department has achieved a remarkably rapid growth since its formation. Starting with only three full-time faculty members in 1969, the Department has grown to a size of 13 FTE, of whom 6 have tenured status. The Department has already conferred five Ph.D. degrees. In addition, seven Ph.D. degrees were awarded in other departments to students supervised by faculty members in MS. In the steady state, the Department expects to be producing about 8 Ph.D.'s per year, compared with the current rate of about 1.5 per year.

During the same five year period, the Department produced 78 M.A.Sc.'s (about 16/year), with the steady state rate expected to be in the neighborhood of 30/year.

Taking the information furnished by the Department at face value, the consultants cannot but be highly impressed by the remarkable achievements of the Department in the development of its graduate programs, building up of a very competent staff and providing off-campus instruction for professional engineers in Waterloo, Toronto, London and other locations.

Although the initiatives taken by the Department in the pursuit of its educational and research goals are highly commendable, they raise some non-trivial questions regarding the relationship between Management Sciences and Systems Design in the years ahead. A case in point is the initiation of a new Industrial Engineering B.A.sc. option in Mechanical Engineering which will be administered jointly by Management Sciences and Mechanical Engineering. This program is likely to compete with the undergraduate program in Systems Design and as a result may lead to a strain in the relations between the two Departments.

The overlap between the activities of Systems Design and Management Sciences is quite significant in the areas of socio-economic systems, optimization and conflict analysis - areas in which the Department of Management Sciences appears to have a high level of expertise than Systems Design. On the other hand, the Department of Systems Design is clearly stronger in the areas of systems theory, human systems engineering, systems modeling and simulation, and computer-aided design. In these areas, the overlap with Management Sciences is slight or nonexistent.

In relation to the degree of overlap in the interests of the two Departments, the level of cooperation between them is rather minimal. There are no jointly offered courses, nor are there joint research projects. More important, there does not appear to be a mechanism for the coordination of graduate programs, new course offerings and new appointments. The absence of such a mechanism may, in time, lead to serious conflicts over the allocation of resources, recruitment of faculty and the initiation of new programs.

In making this statement, the consultants should like to make it clear that they are not advocating a tightly enforced coordination of the activities of Systems Design and Management Sciences. Excessive coordination can have a stifling effect on the initiatives of the departments in question and may be counterproductive in increasing the level of interaction between them. Thus, what is needed is an informal arrangement for coordinating the teaching as well as research activities, backed by a clear expression of policy on the part of the Dean of Engineering to the effect that Systems Design and Management Sciences must cooperate with one another in order to receive favourable consideration of their requests for additional resources in manpower and/or physical facilities.

In summary, the level of cooperation between Systems Design and Management Sciences appears to be quite limited in relation to the degree of overlap between their interests. There is a potential for serious conflicts between the two Departments if no attempt is made to widen their channels of communication and encourage their cooperation in both teaching and research.

University of Waterloo
Department of Systems Design

5.9 Recommendations

In concluding their assessment of the graduate program in Systems Design at Waterloo, the consultants have the following recommendations to offer.

1. Require higher qualifications of new appointees and raise the standards for advancement to tenure. To prevent excessive inbreeding, graduates of the Department should not be employed on a regular basis. The existing vacancies should be filled only after a thorough search for best available candidates. This recommendation reflects the consultants' feeling that the quality of some of the recent appointments to the faculty is open to question. Considering the high reputation of Waterloo and the current state of the academic marketplace, the Department can, and should, set very high standards for initial appointments and fill a vacancy only if the candidate has outstanding qualifications and has high potential for future growth.

2. Review both undergraduate as well as graduate course offerings with a view to eliminating or tightening those courses which have excessively "soft" content. Place more emphasis on computer simulation, computer graphics, and computer-aided design. Not a few of the courses offered by the Department (e.g., SD 631, Games Metagames and Rationality; SD 668, Design Morphology and Organization; SD 671, Theory of Human Communications) appear to be lacking in "hard" content. It is essential that the Department maintain high standards in its graduate course offerings and put more emphasis on computer-oriented subject areas.

3. Increase the level of interaction with other departments especially with Electrical Engineering in the areas of systems theory, computer simulation and control processes; with Computer Science in the areas of computer systems, information systems and computer graphics; with Psychology in the areas of human systems engineering; and with Management Sciences in the areas of socio-economic systems, optimization techniques and conflict analysis. The tightness in the University budget and the likelihood that resources for expansion will be very limited during the next few years, dictate the need for a far greater degree of cooperation and resource-sharing among the departments in the Faculty of Engineering than was necessary in the past.

4. Avoid fractionation of Departmental activities into a large number of unrelated areas. Major areas of teaching and research should be dealt with in greater depth. The heterogeneous nature of the subject areas falling within the scope of Systems Design makes the maintenance of a sense of unity within the Department a rather difficult problem. The consultants noted that some of the faculty members tend to spread themselves too thinly and undertake a variety of external responsibilities

which interfere with the conduct of substantive research and make it difficult to maintain a high level of competence in their field.

5. In relation to Management Sciences, avoid duplication of course offerings and deemphasize areas of activity in which Management Sciences has much greater expertise. Set up a committee to coordinate the offering of new programs and increase the level of interaction between Systems Design and Management Sciences. A great deal of thought must be given to ways in which Systems Design and Management Sciences could develop a symbiotic relationship with one another. It would be highly desirable to have a mechanism - such as a committee or an informal group of faculty - to coordinate the activities of the two Departments in areas of common interest in order to avoid misunderstandings that may evolve into more serious conflicts over the allocation of resources and the definition of spheres of influence.

6. Take steps to increase the visibility of the Department both nationally and internationally. At present, the Department is not as well known as it deserves to be. To enhance its visibility, the Department and its faculty members might consider taking a more active role in the organization of seminars and conferences on subject areas within Systems Design in which the Department has strong programs. Also, better publicity in the form of posters, pamphlets and letters would be helpful.

A P P E N D I X C

UNIVERSITY COMMENTS

Comments appear from Toronto, Waterloo and Windsor.

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto 181, Canada

April 22, 1974

Professor M.A. Preston,
Council of Ontario Universities,
#8039,
130 St. George Street,
Toronto.

Dear Dr. Preston,

The consultants' report on Industrial Engineering has offered some useful comments on this university. We have no major criticisms so far as the report relates to this university. There are some errors, however, and a number of points of clarification on the main recommendations. The numbers below follow those used in the report.

1.2. The Department of Industrial Engineering at this university was formed in 1961, not in 1958 as stated in the report. The period 1958-61 was a transition period during which the then extant Engineering and Business course, which was formed in 1949, was given a more rigorous scientific and engineering basis.

The distinction drawn between the respective programs at the University of Toronto, Waterloo and Windsor should not be interpreted too literally. For example, all three programs are concerned with man-machine systems (as indeed ipso facto are all engineering disciplines). On the other hand, we are conscious of the importance of maintaining and emphasizing the distinctive characteristics of the respective Departments under consideration.

2.0. Overall Recommendations

1. We endorse this recommendation

2. We endorse this recommendation

3. We object to the use of the word "quota" which we believe gives a meaning to this recommendation not intended by the consultants and is inconsistent with their comments on manpower elsewhere in the report. There is no indication of oversupply in this discipline and some evidence that far more graduates will be needed. If, for example, as seems probable, large-scale programs in health systems and in energy systems are launched within the next two years, it is possible that, by 1979, the Toronto Ph.D. output might reach six or seven graduates per year.

4. We agree in principle with this recommendation, especially insofar as the necessity of avoiding undue duplication of course offerings is concerned. However, we do not accept the implication that the three Departments operate in a competitive mode, for there is appreciable evidence of co-operation between the Departments. Indeed, there is some thinking that they are not competitive enough in some desirable respects.

5. We agree in principle and much effective counselling of this kind now goes on. On the other hand, it would not be justifiable for the Ontario IE (and equivalent) Departments to establish the proposed counselling structure without bringing all Canadian IE Departments into the structure in some way.

6. We endorse this recommendation.

7. Toronto agrees that Faculty in IE-related Departments provide valuable resources to the total University structure. We are very much in favour of such interaction. At the same time, we are not clear as to what operational significance to attach to comments in consultants' (and ACAP) reports to the effect that this has not been "sufficiently exploited".

At Toronto, for example, three members of the II Faculty are cross-appointed in the Institute of Environmental Studies; two members of the II Faculty are members of the Council of the Centre for Culture and Technology; co-operative teaching and/or research programs are being, or have recently been undertaken with the Department of Family and Community Medicine, the Faculty of Management Studies, the Institute for Quantitative Analysis, the Department of Psychology, the Faculty of Library Science, the University Library, and several others. Furthermore, essentially due to this inter-disciplinary characteristic and the concomitant ability to traverse departmental boundaries, it is perhaps not out of place to mention that a member of the faculty, during a two-year leave of absence, at the invitation of a major Ontario university, undertook a study of the "structure and inter-relationship of the academic programs of the University".

At the same time, we do accept the point as it relates to Information Systems (see 3.3 below).

9. Our Department endorses this recommendation and notes that there is already a reasonable balance between theoretical and "real-world" components and problems in the Department's Ph.D. programs. Indeed, had time been available during the visit of the consultants, it would have demonstrated, through fourth year theses and M.A.Sc. theses, as well as the Ph.D. theses, that there has been, since the formation of the Department, concern at a reasonable level with 'real-world' problems.

10. We endorse this recommendation.

11. We endorse this recommendation. It might be of interest to note that at Toronto, one woman Ph.D. student and five women Master's students are registered in I.E.

3.3. Overall Perspective

Some of the historical information is not quite accurate. As pointed out earlier, the Department of Industrial Engineering at Toronto was inaugurated in 1961. The program in Engineering and Business was phased out during the period 1958-60. Graduate study in the Department commenced formally in 1962. Dr. Arthur Porter was succeeded as Chairman by Dr. Ben Bernholtz in 1968 (not 1966).

The Department has already made the second appointment in the Human Factors area, as recommended by the consultants.

The Department also endorses the view that the identity of the Information Systems group has not been recognized sufficiently in the Faculty and that a "strategy to project the IE Department as leaders in this activity' should be developed. The Department hopes to remedy this deficiency at least in part through inter-disciplinary projects in the Health System and Energy System areas.

We agree that the total elapsed time to obtain the Ph.D. in IE appears to be excessive. But the data presented on page A-31 are not quite complete - this topic will be considered in detail a little later.

3.5. Faculty Quality and Size

We suggest that some revisions are necessary in this section, especially in the following :

(a) The number of Faculty (listed in the Calendar of the School for Graduate Studies) increased from 9 in 1968-9 to 13.1/2 in 1973-74.

(b) Although at present only two Ph.D. students in IE are supervised by the Human Factors Engineering Group, it should be noted that one Professor in this field is also supervising two Ph.D. students in the Departments of Electrical Engineering and Psychology.

(c) The levels of sponsored research (obtained from the Dean's office) mentioned on page A-17, have been determined solely on the basis of N.R.C. Grants. While the total of N.R.C. grants for 1972-73 was only $38,000, it may be pointed out that during that year several senior members of the staff were on leave, full-time or part-time, and did not apply for grants. The picture is rather different for the current year 1974-75, for which the total of N.R.C. grants is $102,000. In addition, there are grants from the Ontario Department of Health ($5,000) and the (U.S.) National Science Foundation ($21,000) for a total of $128,000 in research grants for 1974-75, about $10,000 per member of Graduate Faculty. In addition, we have recently learned of a major award to a senior member of the Department, the only one of its kind awarded in all branches of Engineering in Canada, which will bring a substantial amount of money to the Department for interdisciplinary research.

(d) While admittedly the acquisition of additional unconstrained research grants is an ideal approach to the enhancement of the human factors laboratory facilities and to increasing the stipends of doctoral candidates (there is effectively a $5,500 ceiling on doctoral student awards in the Department) it must be stressed that sponsored research (in Canada) is invariably based on specific projects. Unfortunately, the funding flexibility implied in the consultants' comments (page A-18) is not possible in practice.

Human Factors Engineering

In this area for 1973-74 there is a total of $38,000 in research grants.

Management Information Systems

It should be noted that the interaction with the Faculty of Management Studies is being enhanced. During 1973-74, 11 IE graduate students are taking a total of 24 one-term

courses in the Faculty. While IE and MS have some graduate courses with similar titles, the courses themselves may be different. We should add that the School of Graduate Studies and the central administration have established a small group to look at possible duplication in courses in information systems throughout the University. As the Ph.D. program in quantitative methods in MS develops, it is expected IE will be able to share some courses and seminars.

3.7. Quality of Student Body : Admission Requirements

The data presented in Figure 1 and comments relating thereto might be misleading. For example, it is stated that of the 19 students accepted only 7 students actually registered in the Fall Term. But only 4 students accepted for the Ph.D. failed to register - the remaining 5 students who failed to register were not acceptable in the Ph.D. program. The appropriate sentence should read "of the 24 students who applied for the Ph.D. program, 11 students were accepted for that program, of whom 4 failed to register as of January 1974".

We noted earlier the concern expressed by the consultants on the elapsed time to complete the doctorate. Examination of the 22 Ph.D. theses which have been successfully defended shows that s e v e n were closely related to "real-world" problems and it is not surprising that these take longer to complete than theses which are essentially theoretical. We believe that in many cases the quality of the thesis was enhanced by the candidate's employment experience, though the thesis took longer to complete.

3.8. Recommendations

While much of our response is indicated above, it is worthwhile to summarize briefly our comments on the recommendations.

1. We agree with the spirit of this recommendation and we believe that it will be possible to obtain more interaction between the three major groups in the Department through the comparatively large-scale project which we envisage in, for example, the design of Health Care Systems.

2. Our Department has endorsed this recommendation enthusiastically. Indeed, since the inauguration of the Department in 1961 a major concern has always been with real-world problems. An examination of bachelors, master's and doctors theses during the past decade provides evidence of the Department's efforts in this regard.

3. The current Visiting Professor in Human Factors Engineering will become a Professor with tenure on July 1, 1974.

4. We endorse this recommendation but wish to point out that a good case can be made for maintaining a reasonable balance between full-time and part-time thesis programs, not least to ensure adequate real-world problem orientation.

5. We endorse this recommendation.

6. The Department is fully aware of the need to obtain adequate additional support from external sources and our 1973-74 figures (see above) show a distinct improvement over those for 1972-73.

7. We endorse this recommendation. See comment above on Management Information Systems.

8. We endorse this recommendation, noting that the Department has been conscious of the importance of research in the real-world environment since 1961 when the Department was established.

9. We endorse this recommendation. As we have indicated previously, the Department has already assumed a leadership role in the Faculty in the field of man-machine systems with special reference to human factors engineering.

10. We endorse this recommendation and expect that the Department will assume a significant role in this area.

11. We endorse this recommendation and note the substantial efforts already made by the Department in encouraging interdisciplinary research on this campus.

Yours sincerely,

A.E. Safarian

A.E. Safarian
Dean

cc. The President,
Prof. L.E. Forster
n Itkin
T. Sword

Response of the University of Waterloo to the Report of the Industrial Engineering Consultants to the Advisory Committee on Academic Planning

submitted to ACAP, April 26th, 1974

We agree with the consultants' general view of developments in industrial engineering and systems design. In particular, we agree that the demand for students will likely exceed the supply over the next five-year period. As the consultants point out, only two schools in Canada offer the Ph.D. in industrial engineering and Waterloo's programme in systems design is unique in this country. We agree that the limiting constraint on doctoral enrolment in these programmes will be the number of well qualified applicants, particularly Canadians.

Specific Comments:

In the section of the report devoted to the programme in systems design at the University of Waterloo, the consultants make a number of statements which we would like to comment on.

On Page A-54, the consultants state that "a student who fails his comprehensive examination may take instead an enlarged course-work programme.". This statement is not correct. If a student fails his comprehensive examination, he may be required to take an enlarged course work programme before being allowed to take the comprehensive examination a second time. Every doctoral student, however, must pass the comprehensive before being allowed to proceed to his degree.

On Page A-54 the consultants state that some of the courses offered by the department are "lacking in 'hard' content" by which they seem to mean mathematical content. Some of the courses offered by the department do indeed rely less heavily on mathematical analysis then do courses in more conventional fields of engineering. These courses form an important part of the programme and in our view are quite appropriate in a programme of this nature. While such courses are not mathematically oriented, this does not mean that they necessarily lack "hard" intellectual content. This will be ensured if they are taught by faculty who can provide the necessary rigor and authority

based on their own research and scholarly involvement. If this is not the case, such courses can indeed become "soft" and the university is aware of this danger.

In the section on faculty quality and size, Page A-56 the consultants make two statements which require comment. They state on page A-56 that "the quality of some of the appointments made during the past three years is open to question". If this comment is directed, as it appears to be, to the qualifications of the individuals appointed during this period, then we must take exception to the statement. There have been three appointments during this period. One of these is a senior scientist of international reputation with numerous publications and two books to his credit, a second is a person with a substantial research record and the third is a recent Ph.D. graduate with an excellent record and considerable potential. None are of questionable quality. If on the other hand the comment is directed at the failure of the department to appoint only senior distinguished people then we would point out the difficulty of finding such people particularly in a new field such as systems design. Indeed the consultants themselves recognize this, (see Page A-56, middle). In either case, we submit that this statement must be read in the context of the consultants' overall assessment that "the faculty, on the whole, is competent, active, dedicated and forward-looking.".

The consultants express concern that four out of the fifteen faculty members in the department have received all or most of their training at Waterloo. While we agree with the consultants that excessive inbreeding can be highly detrimental to the development of any department, we do not believe that four out of fifteen faculty can in any way be described as detrimental inbreeding. This is particularly so in this case since three of the four individuals refered to, while they received their senior degrees from Waterloo, have had extensive post-doctoral or pre-doctoral experience elsewhere.

In discussing the quality of the student body, the consultants refer to the heterogeneous disciplinary backgrounds of the students. They suggest that this makes it difficult to enforce high admission standards. We agree that it is more difficult to assess the quality of the students when their backgrounds are diverse but this does not mean that one cannot enforce high standards. The department views the diversity of background of its

students as a valuable and indeed necessary component in the graduate programme. It does not, however, intend to allow this diversity to dilute the quality of its student body.

In the section devoted to relations with the Department of Management Sciences, the consultants note the lack of any joint courses or joint research projects. We do not see the need for joint courses between these two departments since the courses offered by both departments are freely available to graduate students in either.

Comments on Overall Recommendations:

We agree with Recommendations 1 and 2. The text following Recommendation 2, however, needs some clarification. It is true that at the present time the major activity of the department is in the field of human factors and physical systems. The department's plans, however, are to develop a programme with a balance of emphasis distributed over three areas, physical systems (system engineering theory and practice), socio-economic systems (large non-corporate systems), and design and human systems (design for human use).

We agree with Recommendation 3 provided that the word "quota" which is used to refer to the Ph.D. output is interpreted as refering to the planned level of enrolment in these programmes. In view of the consultants own anticipation that demand for graduates from these programmes is likely to increase, it is inconsistent to impose a quota and we do not believe that that was their intent.

We do not agree with Recommendation 4. There is very little overlap between the programmes involved and we doubt the value of establishing a co-ordinating committee.

We do not agree with Recommendation 5. This implies a degree of centralization in admissions procedures and counseling of students which is impractical in the Ontario university system.

We agree with Recommendation 6.

We agree with Recommendation 7. We hope that the field of industrial engineering and systems design will be better funded under the new federal grant structure currently being contemplated. The field has not been

well served by the present grant structure. In addition to research grants, the department at Waterloo has a number of research contracts which support work in the department.

We interpret Recommendation 8 to mean that the valuable resources available in these departments should be taken advantage of to a greater extent by other departments both inside and outside the Faculties of Engineering. We agree with this.

We agree with Recommendation 9. Indeed the Ph.D. programme in systems design at Waterloo is very much oriented towards research on real world problems.

We agree with Recommendation 10. The small number of Canadian students is not unique to systems design and industrial engineering but applies to all of the fields of engineering. This university will continue to make every effort to encourage qualified Canadians to pursue doctoral work in this field.

We agree with Recommendation 11. A number of women students have already been attracted to the programme in systems design. The department will continue its efforts in this direction.

Comments on Specific Recommendations:

Recommendations 1 and 2 refer to matters on which we have already commented.

Recommendation 3 indicates that the consultants in the limited time at their disposal in visiting the university have not been made sufficiently aware of the extensive co-operation and interaction occurring between the Department of Systems Design and other departments in the university. There is close cooperation with members of the Electrical Engineering Department in the field of networks. There is also considerable interaction with the Departments of Civil Engineering and Management Sciences and with the Department of Applied Analysis and Computer Science in the Faculty of Mathematics.

Recommendation 4 is one with which we agree. The department is aware of the dangerof excessive fractionation in a field such as systems design and has consciously endeavored to avoid this in the development of its programme.

We have already commented on the substance of Recommendation 5. In particular, we see no reason for the university to set up a special committee to co-ordinate the offerings of the two departments since this function is already the responsibility of the Faculty of Engineering Graduate Studies Committee.

With respect to Recommendation 6, we agree that the department should continue to increase its visibility both nationally and internationally. We believe that this will occur in the normal course of development of the department and the maturing of the junior faculty. We submit, however, that the department's external visibility is already somewhat greater than is implied by the tone of this recommendation. Several members of the department in the fields of system engineering, engineering design, ergonomics and human factors engineering have already become well known nationally and internationally. Members of the department serve as officers in international organizations and as consultants to government and industry. These activities will continue.

Respectfully submitted,

L. A. K. Watt

L. A. K. Watt
Dean of Graduate Studies

UNIVERSITY OF WINDSOR

RESPONSE TO THE ADVISORY COMMITTEE ON ACADEMIC PLANNING CONSULTANTS' REPORT ON INDUSTRIAL ENGINEERING

Preamble

The Consultants' report on Industrial Engineering at the University of Windsor is an adequate and fair commentary, and the University concurs in general with all five of the Consultants' recommendations. Especially to be noted is the insight into the Provincial situation which is revealed in the following excerpts from the Report:

The Consultants point out that there are only two departments of industrial engineering in the Province of Ontario and that there is an apparent demand for these graduates. They state: "Since no other schools in Canada offer the Ph.D. in IE, it appears that less than 20 people in Canada have received their doctorate in IE from a Canadian University.

Outside the Province of Ontario, industrial engineering studies are available at the Nova Scotia Technical College, Ecole Polytechnic in Montreal, University of Newfoundland, University of Quebec, and the University of Moncton in New Brunswick."

The Consultants also state: "Based on previous data and discussion, the consultants feel that the actual demand will be higher than the supply over the next 5-year period, recognizing that only two schools in Canada offer a Ph.D. in IE...Accordingly...the consultants feel that each department has its own distinctive character, and a significant need does exist for their graduates in educational institutions, industry, government, and service organizations in the Province

of Ontario and other provinces of Canada."

Comments on Consultants' Recommendations

RECOMMENDATION 1 - Continue the doctoral program, but not on high-priority basis.

"It would be unrealistic and wasteful of the limited resources which the Department has at its disposal to attempt to build up a doctoral program that can compete, even remotely, with those at Toronto and Waterloo. The aim should be to have a small-scale program which complements those at Toronto and Waterloo and emphasizes production, mission-oriented type training which fits the needs of the region."

The University agrees with this recommendation and maintains that even now a doctoral program of excellent quality has emerged from our mission-oriented approach to the doctoral program.

RECOMMENDATION 2 - Draw on the resources of other departments for instruction and laboratory facilities.

A concerted effort is being made to extend the concept of this recommendation further. Two graduate courses in the Systems Division--I.E. 509c/E.E. 510c, Computer Aided Design, and E.E. 507c (cross-listed as I.E. 511c in 1974-75 Calendar), Stochastic Processes-as pointed out by the Consultants, are courses in which co-operative teaching arrangements have been implemented. Co-operative team-teaching in other courses and expanded use of outside facilities are planned to follow this September.

The Department is working with the School of Computer Science to explore the cross-listing of faculty and increased co-operative use of the Computer Science facilities and faculty resources. In addition,

the Department is presently exploring a co-operative arrangement with other departments participating in the Process Design Division similar to that it now has with the Systems Division. The following excerpt from the Consultants' report will help to clarify the University of Windsor's Divisional structure:

"The following three divisions were established by the Faculty of Engineering for the purpose of co-ordinatinn graduate studies within the Faculty: Engineering Process Design, Structures, and Systems... The objective of this division organization is to make more effective utilization of available resources and to stimulate interaction among departments in the Faculty of Engineering. The consultants consider this to be a desirable objective to achieve, especially since the number of faculty in any one department at Windsor is relatively small. This divisional structure was initiated in 1972...Due to the involvement of industrial engineers in environmental types of problems, in the future the IE Department should also formally interact with the Engineering Process Design Division."

It should be noted that the divisional structure does not diminish the effective autonomy of the departments, for the departments are still responsible for administering the programs and maintaining the necessary professional standards.

RECOMMENDATION 3 - Make a concerted effort to obtain more research and facilities support from both government and industry.

The Department is now making a concerted effort to acquire additional support for research and facilities, and is happy to report that progress has been made in terms of sponsored research since the writing of the report; two NRC Operating Grants have been awarded

Industrial Engineering faculty members. With these two awards, the average grant support per faculty member is in excess of $10,000 per annum which compares favorably with approximately $4000 for both the Department of Industrial Engineering at the University of Toronto and the Department of Systems Design at the University of Waterloo, as reported by the Consultants.

RECOMMENDATION 4 - Raise the standards of appointment and advancement of faculty.

"The small size of the faculty and its uneven quality make it essential that new appointments and advancements be made with utmost care. Vacancies should be widely advertised, and inbreeding should be avoided."

The University concurs with this recommendation. The Department, however, is not in agreement with the Consultants' subjective statements related to faculty credentials and accomplishments. When it is considered that the thrust of the Department's program is related to production systems, it seems necessary to have faculty with long term industrial experience. Although two faculty members do not have the Ph.D. degree, one has had twenty years' industrial experience in responsible executive positions and is a principle consultant for the Industrial Research Institute, and many independent corporations in Canada. The other faculty member has a firm background in graduate teaching and is currently enrolled in a Ph.D. program.

RECOMMENDATION 5 - Allocate a new position to be filled on a temporary basis.

"At present, the number of full-time faculty members (4) is too small in relation to the totality of the responsibilities of the Department in teaching and research. On the other hand, considering the scarcity

of new positions in the University, the allocation of a full-time position to the Department would be hard to justify at this juncture. Under the circumstances, a temporary addition to the faculty would be a reasonable compromise, with the understanding that, eventually, the temporary position would be converted to a regular full-time one."

The University concurs with this recommendation.

In conclusion: the University accepts the summary recommendation that the doctoral program in IE at Windsor should be supported at a level sufficient to attract quality students and carry them through their graduate studies.

APPENDIX D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Special Study of Ph.D. work in Industrial Engineering at Toronto and Windsor and Systems Design at Waterloo

Procedure and Terms of Reference for Consultants

1. The data usually collected for the engineering assessments will be provided to ACAP by the universities.

2. There will be no discipline group.

3. Two consultants will be chosen by ACAP from a list provided by the universities involved. One consultant (or both) should be from the industrial engineering field and one should have expertise to enable him to comment on the other aspects of the Systems Design programme at Waterloo.

4. The consultants should spend one day at each university.

5. The consultants' terms of reference will be similar to those in the engineering planning assessments. (Those of the Chemical Engineers were given to them.)

6. When the report from the consultants is received by ACAP, each university involved will be invited to comment on the report. Comment will also be sought from CODE.

7. Since the amount of consultant time involved is small, it is hoped that the report will be ready at the same time as the other engineering reports, but it is considered that if this does not happen, its absence need not delay action on the others.

8. The consultants are also asked to write a report of the current and proposed programme in Management Science at Waterloo, discussing its nature and quality. This report to ACAP will also be provided to the consultants in the Administration, Business and Management Science planning study.

MAP:kw

APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,

   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;

   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;

   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;

   (d) "university" means a provincially assisted university in Ontario;

   (e) "discipline" means any branch or combination of branches of learning so designated;

   (f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;

   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;

   (h) "programme" signifies all aspects of a particular graduate undertaking;

   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

(b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities.

(c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

(a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

(b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

(c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

(d) To supervise the conduct of each planning assessment approved by CPUO;

(e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

(f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

(a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

(b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

(c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

(d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

(e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

(f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

(g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

(h) generally to report and to make recommendations to the Council;

(i) to seek and receive advice from appropriate experts;

(j) to employ consultants in connection with planning assessments;

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the Universities of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

APPENDIX G

CURRICULA VITARUM OF THE CONSULTANTS

ALBERT GEORGE HOLZMAN

Born Johnstown, Pennsylvania, October 28, 1921

B.S., Pittsburgh, 1949
M.S., Pittsburgh, 1954
Ph.D., Pittsburgh, 1958

Bethlehem Steel Corporation, Industrial Analyst, 1949-51
University of Pittsburgh, Assistant Professor, 1951-54
Associate Professor, 1954-58
Professor, 1958-
Chairman, Department of Systems Management Engineering and Operations Research, 1965-

Consultant to Westinghouse Electrical Corporation
U.S. Steel Corporation
Defense Intelligence Agency
Goodyear Tire & Rubber Company
H. B. Maynard Research Council

Member, Board of Directors, On-Line Systems, Inc., 1968-
Member, American Society of Engineering Education
Member, American Institute of Industrial Engineers
Member, Operations Research Society of America
Member, Institute of Management Science

Operations research in education administration; optimization theory; technology assessment.

Address: Department of Systems Management Engineering and Operations Research
1048 Benedum Hall of Engineering
University of Pittsburgh
Pittsburgh, Pennsylvania
15213

LOFTI A. ZADEH

Born Baku, Russia, February 4, 1921

B.S., Teheran, 1942
M.S., Massachusetts Institute of Technology, 1946
Ph.D., Columbia, 1949

Columbia University, Instructor, 1946-50
Assistant Professor, 1950-53
Associate Professor, 1953-57
Professor, 1957-59
University of California, Berkeley, Professor 1959-
Chairman, Department of Electrical Engineering and Computer Science, 1963-67

Member, American Mathematical Society
Member, Association of Computing Machinery
Member, Institute of Electrical and Electronics Engineers

System theory; information processing; theory of fuzziness

Address: Department of Electrical Engineering and Computer Sciences
University of California
Berkeley, California
94720

APPENDIX H

RESPONSE OF THE COMMITTEE OF ONTARIO DEANS OF ENGINEERING

COMMITTEE OF ONTARIO DEANS OF ENGINEERING

RESPONSE TO ENGINEERING PhD ASSESSMENTS

Preamble

Individual reports of PhD Assessments have already been received by discipline groups and by individual universities. Both bodies will undoubtedly make detailed commentary on the specific reports which are of direct concern or interest. In view of this, CODE has decided to forego comment on such specifics, and has determined to refer only to those matters of a more general nature which affect the universities collectively. In choosing to frame its response in unitary fashion, CODE wishes, at the outset, to emphasize that it views engineering education and practice as a total activity instead of a discrete set of unrelated disciplines such as Chemical, Civil, Electrical, Materials, Mechanical and Metallurgy, etc. This theme of relationships between disciplines within a faculty, and indeed between faculties, will recur later in the report in subsequent discussions.

Of the ten topics on which CODE sets out its 'responses', three are considered to be of primary importance - manpower, quality, and critical size. Consequently, they have been covered in somewhat greater detail than have other topics of interest, in order to provide identification and emphasis, rather than a fully developed 'position'.

The primary concern in this response is unquestionably that of quality over quantity. In assuming this position CODE realizes that the indicators of quality are undoubtedly staff, students, programmes and facilities. It is difficult to assess the precise hierarchy of these four basic parameters. Suffice it to say that, while the first two are paramount in terms of establishing potential for excellence, the last two are important in realizing this excellence.

CODE offers its resources in such further and subsequent amplification as may be useful to the purposes of the Council of Ontario Universities.

Manpower

CODE is in agreement with the general observations of the consultants with respect to the PhD manpower situation. It appears clear that the supply of PhD candidates will be limited by the availability of high quality entrants. The relatively small numbers of Canadian graduates entering PhD programmes is a cause for concern. If Canada is to advance industrially, it would be expected that there would be an increasing demand for high-technology support. An under-supply of PhD graduates in engineering would not be in the best interest of society. There is clearly no evidence of any

over-supply because of the way engineering graduates at all levels are seen to diffuse widely through industry, commerce and government; there appears no prospect of this becoming a problem in the future.

CODE realizes the importance of maintaining up-to-date knowledge of positions taken by the PhD graduates of the Ontario Engineering schools and intends to ensure that such information is updated annually. A copy of a recent survey is included as part of this response. It will be noted from this survey that there has been a shift in the area of employment of engineering PhD's towards industry.

In the light of the consultants' analyses, and of the appended data, there is no need for quotas or ceilings on doctoral students. CODE will continue to report on the number and origins of doctoral students in the various engineering schools, on an annual basis.

Quality Emphasis

(a) Admission

CODE is pleased to note that the consultants have agreed that high admission standards to engineering doctoral programmes generally prevail.

CODE, therefore, supports the contention that existing minimum entrance standards to PhD programmes should be maintained across the Province. CODE believes that a post facto analysis of admission practices, widely publicized, will be adequate to ensure this objective.

In application of these standards, it must also be acknowledged that certain defensible exceptions will occur with respect to those with known special abilities or those who have demonstrated superior ability in research, design and innovation in their post-baccalaureate experience.

CODE fully supports the view of the electrical consultants that it is "in Canada's interest, especially in international competition, to have strength in high-technology research and development" and for this to happen there must be an objective of "high standards of excellence with emphasis on quality".

(b) Programmes and Faculty Facilities

CODE recommends that totally independent and representative bodies continue to oversee negotiated development grants and the formation of centres of excellence. These are matters better left outside the jurisdiction of such a body as CODE.

(c) Undergraduate/Graduate Programme Relationship

CODE supports the contention that the continued existence of a live, up-to-date undergraduate programme requires the backing of a good

research programme and participation in professional practice by members of the faculty. The research activity, in the prevailing tradition, is most easily met through the provision of Master's and PhD postgraduate programmes.

(d) Quality Indicators

In addition to the observance of university regulations, and the use of high calibre external examiners, the observed career performance of doctoral graduates can be used as a 'quality indicator'.

Critical Size for Doctoral Programmes

In order to be viable, a PhD programme must provide a sufficient range of interaction for the student. He must be exposed to enough faculty members and enough other students to provide adequate breadth of experience and instruction. The adequacy of this breadth cannot be judged exclusively by the size of the department in which he is registered.

The ACAP assessments, by being completely vertical, miss the rich horizontal components which can and do nourish and sustain viable doctoral programmes in both small and large departments and faculties. Resources from other divisions of the university, other engineering departments, industry and, indeed, other engineering faculties must be considered in any realistic analysis of PhD programme viability.

Size is not a sufficient criterion for judging whether a school can offer a PhD programme; there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as can a large school.

Engineering in the Wider Context

CODE would draw attention to the need to view the totality of the PhD programmes in engineering not just in isolation, but also in the context of other related disciplines; e.g. physical, life and social sciences.

To progress technologically in such a way as to improve the quality of life not only in Canada but also in other parts of the world, it is essential that there be work proceeding concurrently in the forefront of various other disciplines which impact on engineering. It is anticipated that increasingly advanced work in various areas will need to proceed in a more integrated fashion and it will be essential to have available high level manpower in the physical, life and social sciences, economics, and management, for instance, together with similar capabilities in engineering.

Research Emphasis and Relevance

As a result of the ACAP Engineering Assessments, there is now readily available information about research projects underway in all the Ontario

Engineering Schools. The system would have profited more had the consultants commented in detail on this information and offered substantiated specific advice on the topics of emphasis and relevance.

CODE feels that PhD programmes in engineering should be flexible enough to cover a broad range of topics. Research activities could and should range from mission-oriented research of an immediate and perceived social or industrial relevance through to very fundamental or basic research. The overall thrust of PhD research programmes should be towards advancing fundamental engineering knowledge required for the solution of present and future engineering problems.

CODE also feels that a plurality of sources of research support is a relatively effective means of ensuring that a broad spectrum of research activity is undertaken within the engineering schools. The existence of a variety of granting bodies, with a spectrum of interests represented, including a significant academic component, appears to be an effective method of control.

Level of Support for Doctoral Students

CODE strongly supports the contention that levels of support for doctoral students must be increased substantially if more Canadian students are to be attracted to entering doctoral programmes in engineering.

It should be noted that foreign graduate students have been willing to undertake PhD studies at the levels of support available and have subsequently filled positions within Canada. Positions have been available for PhD's - these have been filled largely by landed immigrants who have either completed PhD study in Canada or who have come to Canada with a PhD.

The recent increases in both the cost of living and salaries offered by industry to engineering graduates makes it even more urgent that immediate action be taken to increase the support for doctoral students. This is particularly true if post-baccalaureate experience students are to be attracted. Therefore, it is important that more opportunities be available for this particular type of doctoral student in engineering.

Part-Time/Non-Resident Work

CODE would encourage continued experimentation in this regard. It is felt that maintenance of some institutional contact is essential, however. It is felt further that any part-time or non-resident work should normally be by individual arrangement. This would not, of course, preclude special arrangements between a research institution or industry/government laboratories and a particular university or universities.

Inter-University Activities and Facilitating Mechanisms

CODE would support any action designed to increase the effectiveness of the provincial resources in faculties of engineering. The holding of discipline meetings, the sharing of equipment, interchange of credits for

graduate courses, collaboration between groups within various institutions and so on are to be encouraged. It is emphasized that co-operation often involves travel and other expenses that are not always readily available in individual schools and that this matter is worthy of further investigation.

It is noted that inter-university activity is proceeding especially at the 'grass-roots' level and this can be aided and abetted by CODE. It is also noted that various university industrial research institutes and similar agencies have facilitated some inter-university cooperation largely through use of individual expertise existing at various institutions.

The Role of the PhD in Entrepreneurship

CODE feels that entrepreneurial activity by PhD's is something which cannot be legislated. However, it feels further that the PhD has, by virtue of his total background, significantly greater potential for success in such activity than has the member of the general populace. It suggests that there are two avenues of encouragement which can lead PhD's in greater numbers into entrepreneurship. The first depends on the educational institution itself, which must, by appropriate orientation and emphasis, develop an interest in or leaning towards innovation, independent practice, or entrepreneurship. The second depends on progressive government support programmes of various kinds, directed to reaching a 'climate' competitive with that found in other industrial economies of comparable size.

Cost-Benefit of the ACAP Studies

CODE has noted that no major measures are proposed that would greatly enhance the quality of the PhD effort in Ontario. Indeed, CODE records its pleasure at the broad and independent affirmation of the consultants as to the strengths and qualities which have developed in Ontario PhD programmes.

The full programme of ACAP studies is as yet incomplete. CODE has yet to be convinced that the extensive funds and efforts devoted to the studies would not have been better spent in direct support of existing PhD programmes in engineering.

ANS/dd
December 27, 1973

APPENDIX A

REPORT ON THE CODE ENGINEERING DOCTORATE EMPLOYMENT SITUATION, OCTOBER 1973

In November 1973, members of the Committee of Deans of Engineering of the Province of Ontario again supplied data on the status of their engineering PhD graduates during the period November 1972 until October 1973. The results are compared in Table 1 with those for 1972.

Again this year, the majority of the graduates were in Chemical, Civil, Electrical and Mechanical Engineering. The total is up substantially to 177 from 124 in 1972.

Unemployment is up from one in 1972 to three in 1973 (approximately 1.7% of the total).

Approximately 17% have left Canada, which is the same as for previous years and is probably due to the return of foreign students to their home countries.

A notable increase in employment in industry has occurred, up to 33% from 21% in 1972. The number employed in Canadian universities is up to 26% from 21% in 1972. This has been accompanied by a decrease in post-doctoral fellowships from 23% to 11%.

The overall conclusion is that there is still no serious unemployment among recent Ontario PhD graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established.

December 13, 1973.

ONTARIO ENGINEERING PH.D EMPLOYMENT SURVEY 1973

The employment status of one hundred and ninety-two graduates with PhDs in engineering from Ontario universities during the period November 72 to October 73 was determined in November 1973.

ENGINEERING DEPARTMENT OR DISCIPLINE	Unemployed		No professional Employment		Employed in Industry		Employed in Government		Employed in Universities		Postdoctoral Fellowships		Have left Canada		Unknown		TOTALS	
	1972	1973	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Aero/Space	-	-	-	-	1	3	-	-	1	3	4	1	-	-	-	-	6	7
Bio-Medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Chemical	-	1	-	-	4	13	1	3	7	5	7	5	3	2	4	2	26	31
Civil	-	1	-	-	5	7	2	5	3	14	6	5	9	7	5	-	30	39
Electrical	-	-	2	-	9	20	3	2	5	11	7	5	4	9	1	-	31	47
Industrial	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	5	0
Materials/Metals	-	1	-	-	1	6	1	-	1	3	2	2	-	3	-	-	5	15
Management	-	-	-	1	-	-	-	-	1	1	-	-	-	1	-	-	1	3
Mechanical	1	-	-	-	4	9	2	5	6	8	1	1	2	7	2	1	18	31
Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Physics/Science	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	0
Systems Design	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	1	0	4
TOTALS	1	3	2	1	26	58	10	16	26	46	28	19	19	31	12	4	124	177

APPENDIX B

Comments on CEMC Report

"Supply and Demand for Engineering Doctorates in Canada" (July 1973)

Submitted by the Committee of Ontario Deans of Engineering

Commendation of this report can be made in a general sense on two main scores. Firstly, the consultants have, on assignment, tackled in a straightforward manner, what is generally acknowledged to be a most difficult task indeed; where qualitatively it is not possible to assert all possible parameters, and quantitatively, it is not possible to obtain reliable data on all accepted parameters.

Secondly, the consultants have in their report introduced with some care statements relating to the qualifications and limitations of the many elements entering into their predictions, and have emphasized that this is only a beginning - ergo, a very preliminary report.

Within this general context, however, there are a number of criticisms to be advanced.

1. Supply

The methodology has been clearly enunciated, and the assumptions stated. Nonetheless, projections have been made on a three-level approach (high, medium and low), establishing bounds which may well be broken as and when certain assumptions become less or more operative. Some indicators are already present as to the dangers of some of the assumptions.

1.1 Admission requirements are not static, and are increasingly adaptable to the changes in the high school. Three other important aspects must be added. There is, firstly, foundation for expecting a major growth in the number of women entering engineering. Secondly, the "market-place" reaction with a rapid response in the 1st year enrolment to a proclaimed shortage in engineers will continue to be operative. Thirdly, there is further indication that advanced admissions (through the stop-outs returning, through technology graduates admissions, etc.) are increasingly important in enrolment projections. None of these has been clearly taken into account in this report. A further aspect could well be added, which is also ignored in the report, but is less easy to define though it will contribute to the instability in prediction of 1st year enrolment. This relates to measuring the full impact of major educational changes on the Canadian scene. The effect of the CEGEP's in Quebec in particular, as well as of the CAAT's in Ontario, is yet to be clearly perceived, let alone settled into a measurable or stable influence.

1.2 The two data bases selected for examination were the number of master's degrees and the number of baccalaureates. The discarding of the master's degrees/doctorate degrees ratio as credible seems to ignore the very recent development of many doctorate programmes as contributing to a rapid change in this ratio. The total postgraduate effort in engineering in Canada is of such an emerging character that rates of change must be evaluated much more carefully. This is equally true for the baccalaureate/doctoral ratio selected as a data base. The evidence for stabilization in this is slight, and even the selection of three ratio levels is likely subject to major error through neglect of variable factors in an easily perturbed system. The changing pattern in the number of Canadian baccalaureates who earn doctorates outside the country is one further feature of a system which as yet has little maturity or stability in it. This aspect of immigration was noted in the resport as one for which no data was available - which ignores one fully-documented part of the system, the Athlone Fellows.

1.3 The utilization of the baccalaureate/doctoral ratio as a data base for predicting future supply has another feature which is inadequately considered and analysed. This relates to the forces which are operative on graduates of Canadian engineering schools vis-a-vis their proceeding to doctoral work. Graduates of the engineering schools of Canadian universities have never come forward in substantial numbers to undertake advanced study and research. The tradition of such a choice, and indeed the number of opportunities for such advanced work, are relatively new on the Canadian scene. The expansion of the graduate schools over the past decade has been effected therefore by the attracting of students with overseas degrees, particularly from Asia. Many of these students from overseas have been or have become landed immigrants, have stayed in Canada and have taken jobs as PhD's. These jobs have been available, they have not been taken up by Canadians who seem to have preferred to enter the work-force earlier, immediately after obtaining the bachelor degree. There are probably many factors which have conditioned the particular choices of Canadian engineering graduates at the bachelor level, but primarily it is probably a combination of (a) the fact that they have been so readily absorbed into the economy at that level, and (b) the fact that the level of financial support available for graduate study has been too low to make them feel that the sacrifice is worth it. For the near future, unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline. At the same time as the graduate schools in engineering become increasingly well established and recognized, and as high technology factors including its encouragement through government policies increasingly become operative, the opposite effect could well occur. The imprecision therefore in assuming a stabilized bachelor/doctoral ratio is greater than assumed in the CEMC study.

1.4 In the consideration of the report, moreover, one should not perhaps overlook the possible impact of events occurring in other jurisdictions. The report suggests that the annual number of bachelor degree graduates will fall from about 4,500 to 3,000 over the next three years, with most of this decrease due to a falling-off in freshmen enrolments in provinces other than Ontario. This could suggest in itself a likelihood of fewer qualified Canadian graduates available for PhD studies at our universities. This must be viewed in conjunction with the situation in the U.S. where undergraduate enrolments in engineering have fallen very sharply over the last few years and this will lead to a very substantial decrease in the number of bachelor engineering degree graduates over the next few years. The combined Canada/U.S. graduating class was about 47,000 in 1971. It will be only about 35,000 in 1975. One might wonder whether, because of excellent opportunities at the bachelor level, a smaller proportion might proceed to PhD work or conversely whether the lack of anxiety about employment prospects at the bachelor level will give more students the confidence to continue with their studies.

1.5 A further major criticism of this part of the report rests not on the methodology, elements of which have been discussed above, but on the basic data used in the calculation steps. Without examination of each and every set of data used, it can nonetheless be indicated that the rather complex combinations of undergraduate enrolment and graduation data from Statistics Canada, from EIC enumerations, from the "Ring of Iron" for Ontario leave some inconsistencies. The number of bachelor's graduations and of doctorates were obtained only to 1970-71, while the number of master's degrees were recorded for 1971-72. In view of the rapid build-up in Canada of doctorate degrees (from 78 in 1965-66 to 216 in 1970-71) it would have seemed to be quite important to establish the 1971-72 figures before final projections were carried out. In view of the prominent place taken by the Ontario system contribution it is indeed surprising that more current data at hand in COU (ACAP) was not utilized. Nonetheless, it is fair to point out that the actual doctorates in Ontario for 1972 and 1973 respectively were 124 and 177, and that the former figure compares to the low level projection for 1971-72 of 126, and the latter to the high level projection of 172 for 1972-73. At least the projection band width used just encompasses the first stages of comparative actual data.

2. Demand

The report includes a comprehensive survey of manpower demand methods, and a careful statement of the method followed for each of the sectors explored, as well as its limitations. This demand aspect of the report is the one which has received the most criticism from the ACAP consultants in the five engineering fields assessed. Our criticisms encompass the major elements of those comments in summary form as well as those voiced by the engineering schools in Ontario.

2.1 Educational Sector

The consultants' use of a model for the estimation of future demand in the educational sector is deceptively attractive. Essentially, their model was based on a staff-student ratio as a base, adjusted for retirement, mortality and migration. They concluded that to 1977-78 (at least) the demand for engineering doctorates would be essentially zero, and then admitted "this will not prove to be an accurate scenario". They then rest their case that in both universities and other educational institutions, the demand will be "minimal". In the dictionary sense of the least attainable or extremely minute in size, it is difficult to read into this other than essentially no demand. Even though rather elegantly derived, we find it hard to accept such a conclusion, particularly when the Ontario system itself projects now a demand for about 20 for 1974. Some of the parameters which would be omitted by the model used include increased demand through major block research grants, through mission-oriented research, and through the development of new programmes and areas. The report does deal at length with the question of "substitutability between inputs", but does not weigh it to the level where it would not be balanced by other factors. This question of substitution will also be referred to below in considering the total demand-supply picture.

2.2 Government and Industry Sectors

In these sectors the consultants chose to establish stock data and forecast demand for 1974, 1975 and 1978 by direct survey. From the many criticisms and indeed specific refutations that can be made, it is clear that this survey has been far too narrowly cast. In the government area this is certainly true regarding the narrowness of definition used. In the industry area it includes not only that limiting factor, but became subject to both incomplete data through using wrong sources, and through important omissions. To some degree the consultants were well aware of these deficiencies, but were obviously more conscious of them for the forecast demand data than for the stock data - where equally gross errors and omissions seem to have occurred. One example of such an error is in the stock of 52 in 1973 attributed to AECL, compared to the 90 actual in 1973 as provided by the Metallurgical engineering consultants in their report to ACAP. Other reports to ACAP specify other examples.

It is hard to escape the conclusion that the inadequacies of the demand survey are far greater than the consultants envisioned, and their errors of omission are much greater than they estimated.

3. General

3.1 Educational Planning and Manpower

What appears to be a basic premise of the report as contained in paragraph 1 on page (1) deserves comment, viz.,

> "Now, a generally accepted view is that the expected labour market for graduates of a particular speciality should influence policy and planning in post-secondary education in that area."

This view may not be as generally accepted as one might be led to believe. The particular philosophy outlined can, taken to extremes, result in a shortsighted and constrained view of a university. It could well be argued that too marked a distinction has been drawn between what is educational and what is vocational. Recently this has been convincingly stated to be one of the major misconceptions in higher education planning*. The danger in assuming that all but preparation of people for specific jobs is wrong or wasteful is not just in the short-sighted effort to establish a one-to-one relationship between education and jobs. Rather it omits the important fact that vocationally oriented education is not wasted if it is not used in the specific vocation toward which it was directed. As Bowen* states, "It is no mark of failure, rather a mark of success, that education - even strictly vocational education - has wide applicability and produces flexible and versatile people". The PhD graduate even if he takes a vocational route initially may well very soon find himself in positions where his PhD can be regarded only as part of his general education or as a contributing factor to his intellectual development or problem-solving ability. It is not difficult to give examples of this "diffusion" of PhD's through a "vocational" period to positions of quite different responsibilities in industry, governments and the universities. The consultants gave careful attention at one stage in their report to this "diffusion" or dispersion, referring properly to the recent University of Toronto study. However, they did not then "factor" it in to either their supply or their demand projections. In our view, significant allowance should be made for it. On the supply side, both into the baccalaureate stream as well as into the doctoral stream in engineering the vocational/educational issue is not clear-cut nor should it be. On the demand side, there must be allowance made both for the substitutability through flexibility even at initial employment levels, and for increasing mobility and transfer into wider areas such as management as experience accrues. The difficulty of quantifying this is well appreciated. The need for including it in some definitive way demands equal appreciation.

3.2 The Supply and Demand Balance

The report in its final results and conclusions comes down strongly on the prediction of an oversupply of engineering PhD's in the decade ahead. They acknowledge a range of factors which will influence both their supply band projection and their demand band projection, including the possible effect of their own report. We acknowledge this danger and can only hope that it can be minimized by vigorous emphasis both

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* H. R. Bowen, "The manpower vs. the free-choice principle", University Affairs, Jan. 1974.

on the limitations of the report's projections but also on the countering evidence as it accumulates. We have indicated some of the aspects of both the supply and the demand projections which can invalidate the narrowness of the band widths selected. Perhaps more importantly in the long run is the real failure of any demand projection to be able to take into account any but the very short-term skill requirements of the economy. The evidence is quite clear that our society has an enormous amount of work to be done with a lack of sufficient skilled manpower to do it. We would claim that the adaptability of doctoral graduates in general combined with the adaptability of our economy results in a surprisingly good balance. The Ontario experience, well documented now for four years, indicates essentially no unemployment of engineering doctorates, no unusual hold-up or storage in a post-doctoral form, and changing flows into government and industry as demand from the universities slacken. The acceptance of a current balance, which does exist (with some evidence indeed of unfilled needs in some areas), could well be the starting point for the report's projections. The graphical summary given on page 18 would then present an entirely different picture.

We should rise above our national tendency to be cautious and pessimistic, recognize that even a PhD may be viewed as vocational or educational (hopefully both) according to the graduates perception of the market-place, alternative opportunities, his own desires and so on, and not deliberately cut back on PhD enrolments in engineering, especially on demand data of such doubtful validity as that contained in the CEMC preliminary report. We have so little to gain and so much to lose by taking such an approach. We need to display more optimism and confidence in ourselves and in the ability of highly educated manpower to seek out and create opportunities and to raise the level of some existing positions both in government and industry. It is to be hoped that our students also will display such optimism and take a broader view of the value of their education, and that this view is shared by our federal and provincial governments. We will need this spirit if we are to move into an era in Canadian industry where increasing sophistication and high technology become more and more necessary.

NOTES

Re: 1.1

Entrance to engineering was assumed constant on a demographic base, i.e. 0.5% of male population age 15 to 19; and assumed unchanged entrance requirements.

Re: 1.2 and 1.3

The greatest danger in assuming the validity of a stable B/D ratio for projection purposes resides in the fact that the doctorate figure for the last decade includes a very large but unknown number who did not come through the Canadian baccalaureate stream. The size of that group of doctorates was related largely to immigration policies (now changed and changing), to research grants policies (which have also changed), and possibly to more selective admission policies. Perhaps a meaningful B/D ratio could usefully be established when the D number arises almost entirely from the B stream. Such data have not been collected.